Joint Meeting of the American Society for Gravitational and Space Research (29th annual meeting)

International Symposium for Physical Sciences in Space (5th meeting)

Program and Abstracts

November 3-8, 2013
Orlando, Florida, USA
Joint Meeting of the
American Society for Gravitational and Space Research
(29th annual meeting)

International Symposium for Physical Sciences in Space
(5th Meeting)

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November 3-8, 2013
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27th Symposium on Gravity-Related Phenomenon in Space Exploration

Funding for this conference was made possible (in part) by grants from the National Aeronautics and Space Administration. The views expressed in written conference materials or publications and by speakers and moderators do not necessarily reflect the official policies of NASA; nor does mention of trade names, commercial practices, or organizations imply endorsement by the U.S. Government.

ASGSR Leadership would like to acknowledge the following sponsors and their special contributions at the 2013 annual meeting:
Center of the Advancement of Science in Space (CASIS) as partial sponsor of the student mixer, and two new Student ISS research awards;
Techshot as partial sponsor of the annual banquet and speaker;
Lockheed-Martin for providing travel funding to allow our student officers to attend the meeting; and
North Carolina Space Grant for providing superior administrative support

Corporate sponsors:
Platinum Plus Sponsors: Lockheed Martin, CASIS, Techshot
Platinum Sponsors: Science and Technology Corporation
Gold Sponsors: Astrium North America, Logyx LLC, Universities Space Research Association
Silver Sponsors: Bionetics, CSS-Dynamac, Wyle, Orbitec, Zin Technologies, Space Florida, North Carolina Space Grant
Regular Sponsor: Swedish Space Corporation
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A Tribute to Dr. Michael J. Wargo: 147
Hilton Lake Buena Vista Meeting Room Map: Inside back cover
Dear Colleagues,

On behalf of ASGSR President Joe Tash and ISPS Chairman Fran Chiaramonte, we are delighted and excited to have you here in Orlando, Florida, U.S.A, attending our joint annual meeting of the American Society for Gravitational and Space Research (ASGSR) and the International Symposium on Physical Sciences in Space (ISPS). This is the 29th Annual meeting of the ASGSR and the ISPS’s 5th Biennial meeting; the first time the two societies have met together.

We hope you find the meeting program rich and varied, combining the scientific, technological, and educational activities of both societies. We also hope you benefit from the wide range of approaches, activities and opportunities presented relating to space and gravitational life and physical sciences from around the world (and beyond). This is an auspicious year for life and physical scientists interested in gravity and space effects. The International Space Station is now complete and ready to support quality science using both research opportunities sponsored by the varied national space agencies plus the U.S. non-profit Center for the Advancement of Science in Space (CASIS).

This year’s Plenary Session includes presentations by leaders of the major governmental agencies who head research programs conducted by ASGSR and ISPS members, with overviews and updates on their research programs, funding opportunities, and plans relevant to the attendees. There are Symposia on Developments in Space Radiation Health Risks & Countermeasures, Suborbital Microgravity Research, and an Intro to Physical and Life Sciences Microgravity Research. There are also multiple workshops including ISS National Lab Research Programs and Opportunities (organized by CASIS), a hands-on Education and Outreach Workshop where participants can learn outreach strategies from the Museum of Science-Boston among others, and NASA Life Science Proposal Writing.

The days and early evenings will be filled with topical paper sessions, poster sessions, educational forums, technology updates, and many occasions for informal interactions and discussions with new friends and old – all of whom share interests and passions in space, gravity and the life and physical sciences.

Both the ASGSR and the ISPS will conduct their annual business meetings, committee meetings, editorial get-togethers, and strategic planning sessions. And, of course we’ll eat and drink together repeatedly, but no meal will be more enjoyable than the ASGSR/ISPS Banquet on Thursday night, featuring awards and cheers for one another, as well as featured guest speaker Astronaut Don Pettit to regale us all together with his “Techno-Stories from Space.”

We hope you enjoy the 2013 program, and look forward to seeing you next year at the 30th annual ASGSR meeting scheduled for October 22nd - 26th, 2014 at the Westin in Pasadena, California, U.S.A.

Best wishes,
Howard G. Levine

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**ASGSR Governing Board**

Joseph S. Tash, President  
*Univ of Kansas Medical Center*

Melanie Correll, 2014  
*University of Florida*

Simon Gilroy, President-Elect  
*Univ of Wisconsin, Madison*

Marcia Harrison, 2014  
*Marshall University*

Cynthia Martin-Brennan, Executive Director  
*Bristow, Virginia*

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*NASA Ames Research Center*

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*Kansas State University*

Elison Blancaflor, 2014  
*The Samuel Roberts Noble Foundation*

Heike Sederoff, 2013  
*North Carolina State University*

Kevin Sato, 2015  
*Lockheed Martin*

Robert Morrow, 2013  
*Orbital Technologies Corp.*

R. Mike Banish, 2015  
*Univ of Alabama, Huntsville*

Barry H. Pyle, 2013  
*Montana State University*

Fran Chiaramonte, 2015  
*NASA Headquarters*

Gioia D. Massa, 2013  
*NASA Kennedy Space Center*

Robert Ferl, 2015  
*University of Florida*

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**2013 Meeting Organizing Committee**

Howard Levine, Chair; Board Members: Joseph Tash, Melanie Correll, Jeffrey Smith, Robert Ferl, Fran Chiaramonte; David Tomko (NASA HQ); Cindy Martin-Brennan and Jobi Cook (ASGSR)

**ASGSR Student Association**

Susan John, President  
*Univ of Louisiana, Lafayette*

Andrea Edge, Vice President  
*Univ of Louisiana, Lafayette*

Ashley Cannon, Secretary  
*University of Texas, Austin*

Naveenan Thiagarajan, Treasurer  
*Auburn University*

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**Gravitational and Space Research** is the refereed journal of the American Society for Gravitational and Space Research.
Message from Executive Director:

Because of your support, we continue to be a public forum for gravitational and space research, technology, scientific discovery and training the next generation of scientists. We promote gravitational and space research through special events, increase opportunities for students to become involved, and give policymakers the scientific knowledge they need to make informed decisions. We continue communications through our newsletters, website, membership updates, and referred journal. We value our international relationships and will continue to grow these relationships. With the commercial spaceflight industry leading the development of new launch capabilities we will increase collaboration with commercial spaceflight providers. I just wanted to share with you a few metrics over the last few years so you can see the growth of our organization. Your continued membership with ASGSR is very valuable to us. We had many accomplishments thanks to you!

- The 2012 annual meeting was the largest attendance record in a decade. The 2013 meeting attendance is estimated to be even larger than 2012 with increased international participation;
- Our name was changed to the American Society for Gravitational and Space Research (ASGSR) and became incorporated in the state of Virginia;
- Continued outreach with policy makers and stakeholders; over 75 contacts were made in Spring 2013;
- Student outreach panel in Washington, D.C. on Capitol Hill held in March 2013. Panel sponsorship included ASGSR, CASIS, AIAA and Air Force Recruitment Office.

Respectfully yours,

Cynthia Martin-Brennan
American Society for Gravitational and Space Research

MARK YOUR CALENDARS!

30th annual meeting of the
AMERICAN SOCIETY FOR GRAVITATIONAL
AND SPACE RESEARCH

PASADENA, CALIFORNIA, USA
The Westin Pasadena
October 22—26, 2014

Nestled at the base of the majestic San Gabriel Mountains, less than 10 miles northeast of downtown Los Angeles, Pasadena is quintessential Southern California. From mountains caressed by the sun, through gardens radiant with roses, to extraordinary turn-of-the-century architecture, there is nowhere else quite like Pasadena. With its enviable location and a population of only 140,000, Pasadena offers visitors a friendly and safe enclave. The city’s mild Mediterranean climate also makes for ideal sightseeing conditions. In addition to all of this, Pasadena is easily accessible to all Los Angeles area airports, freeways, and other Southern California attractions, including Universal Studios, Disneyland and local beaches. To make sightseeing even easier, visitors can hop aboard the Gold Line light rail system. The 13.7-mile Gold Line transports passengers from Pasadena to downtown Los Angeles and points in between.
Welcome Reception
Monday, November 4th, 2013

Event Agenda

6:45 pm Bus loading begins at Hilton Convention Entrance

7:00 pm Buses depart

7:20 pm Arrive at EPCOT®: Guests escorted to Terrace Des Fleurs (EPCOT® World Showcase - France)

Cash Bar

7:30 - 8:30 pm Reception on Terrace Des Fleurs and Rue de Paris

9:00 pm IlumiNations: Reflections of Earth - an incredible symphony of lasers, music, and fireworks

9:30 pm Return to Hilton on your own via complimentary Disney transportation services; passenger pick up located in the off-property bus area, parking spots C-29 and C-30; bus will have a Disney logo (red) on side with sign that reads ‘Hilton Downtown Disney.

BE SURE TO HAVE YOUR RED ARM BAND BEFORE YOU BOARD THE DEPARTURE BUS. IF YOU ENTER THE PARK EARLIER ON YOUR OWN, CHECK WITH MEETING REGISTRATION TO GET YOUR RED ARM BAND FOR ACCESS TO RECEPTION.
### General Daily Schedule

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<td>East Registration</td>
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<tr>
<td>12:00 pm – 5:00 pm</td>
<td>Set up – Exhibitors</td>
<td>Center</td>
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<tr>
<td>12:00 pm – 5:00 pm</td>
<td>Set up – Investigator and Student Posters</td>
<td>South</td>
</tr>
<tr>
<td>4:00 pm – 6:00 pm</td>
<td>ASGSR Governing Board Meeting</td>
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<tr>
<td>7:00 am – 8:30 am</td>
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<td>Center</td>
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<tr>
<td>8:00 am – 5:00 pm</td>
<td>Investigator and Student Posters – All Day</td>
<td>South</td>
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<td>8:00 am – 12:00 pm</td>
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<tr>
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<td>Morning Break Service</td>
<td>Grand Foyer</td>
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<tr>
<td>12:00 pm – 2:00 pm</td>
<td>Lunch (on your own)</td>
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<td></td>
<td>ASGSR Membership Committee Meeting (12:00-1:00 pm)</td>
<td>Narcissus</td>
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<td>Salon V</td>
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<td>2:00 pm – 3:30 pm</td>
<td><strong>Workshop II:</strong> CASIS – The ISS National Laboratory</td>
<td>Salon I-IV</td>
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<td>Salon VI</td>
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<td>6:45 pm – 10:00 pm</td>
<td>Fireworks Reception at Disney’s Epcot*</td>
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*Epcot Reception Logistics:*

- All participants MUST have a red wrist band
- Load chartered buses between 6:45 – 7:00 pm (Convention Entrance – Grand Foyer); Buses depart Hilton at 7:00 pm
- Epcot reception 7:30 – 9:30 pm (group will be escorted to French Island – reception location)
- Return to Hilton on your own via complimentary Disney transportation services; passenger pick up located in the off-property bus area, parking spots C-29 and C-30; bus will have a Disney logo (red) on side with sign that reads ‘Hilton Downtown Disney.’
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<td>8:00 am – 5:00 pm</td>
<td>Investigator and Student Posters – All Day</td>
<td>South</td>
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<tr>
<td>8:00 am – 10:00 am</td>
<td>Concurrent Sessions 9-11</td>
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<td>Materials Science 3 (C10) Salon VII</td>
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<td>DECLIC 1: Past, Present and Future (C11) Salon V</td>
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<td>8:30 am – 12:00 pm</td>
<td>Symposium I: Space Radiation – Risks, Research and Countermeasures</td>
<td>Salon I-IV</td>
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<td>10:00 am – 10:30 am</td>
<td>Morning Break Service</td>
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<td>10:30 am – 12:00 pm</td>
<td>Concurrent Sessions 12-14</td>
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<td>DECLIC 2: Near-Critical Fluids Phenomena (C14) Salon V</td>
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<tr>
<td>12:00 pm – 2:00 pm</td>
<td>Lunch (on your own)</td>
<td>n/a</td>
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<td>ASGSR Education and Outreach Committee Meeting (12:00-1:00 pm)</td>
<td>Narcissus</td>
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<td>Information Session II: Market Driven Space Research (12:00-1:00 pm)</td>
<td>Salon I-IV</td>
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<td>ASGSR Journal Committee Meeting (1:00-1:00 pm)</td>
<td>Orange Blossom</td>
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<td>Workshop III: Fluids for Biology Workshop (1:00-2:00 pm)</td>
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<td>Concurrent Sessions 15-19</td>
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<td>Biophysics 1 (C19) Crystal</td>
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<td>3:30 pm – 4:00 pm</td>
<td>Afternoon Break Service</td>
<td>Grand Foyer</td>
</tr>
<tr>
<td>3:30 pm – 6:30 pm</td>
<td>DECLIC Team Meeting (by invitation)</td>
<td>Poinsettia/Quince</td>
</tr>
<tr>
<td>4:00 pm – 5:00 pm</td>
<td>Concurrent Sessions 20-24</td>
<td>Vertebrates 2 (C20) Salon VIII</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Plants 2 (C21)    Salon V</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fluid Physics 6 (C22) Salon VI</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Materials Science 6 (C23) Salon VII</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Acceleration Measurements/Suborbital Flights (C24) Crystal</td>
</tr>
<tr>
<td>5:00 pm – 5:30 pm</td>
<td>Information Sessions III-IV</td>
<td>Express Rack Facility Salon VI</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Microgravity Science Glovebox Salon VII</td>
</tr>
<tr>
<td>6:00 pm – 8:00 pm</td>
<td>Official Investigator and Student Poster Session and Reception</td>
<td>Int’l Foyer/Center/ South</td>
</tr>
</tbody>
</table>
## General Daily Schedule

**Wednesday, November 6, 2013**

<table>
<thead>
<tr>
<th>Time</th>
<th>Event</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>7:00 am – 5:00 pm</td>
<td>Registration Open</td>
<td>East Registration</td>
</tr>
<tr>
<td>7:00 am – 8:30 am</td>
<td>Continental Breakfast</td>
<td>International Foyer</td>
</tr>
<tr>
<td>8:00 am – 5:00 pm</td>
<td>Exhibits – All Day</td>
<td>Center</td>
</tr>
<tr>
<td>8:00 am – 5:00 pm</td>
<td>Investigator and Student Posters – All Day</td>
<td>South</td>
</tr>
<tr>
<td>8:00 am – 10:00 am</td>
<td>Symposium II: Suborbital Microgravity Research</td>
<td>Salon I-IV</td>
</tr>
<tr>
<td>8:00 am – 10:00 am</td>
<td><strong>Concurrent Sessions 25-26</strong></td>
<td><strong>Salon VI</strong></td>
</tr>
<tr>
<td></td>
<td>Fluid Physics 7 (C25)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>DECLIC 3 – Solidification Studies (C26)</td>
<td></td>
</tr>
<tr>
<td>10:00 am – 10:30 am</td>
<td>Morning Break Service</td>
<td>Grand Foyer</td>
</tr>
<tr>
<td>10:30 am – 12:00 pm</td>
<td>Workshop IV: Education and Outreach Workshop</td>
<td>Salon I-IV</td>
</tr>
<tr>
<td>10:30 am – 12:00 pm</td>
<td><strong>Concurrent Sessions 27-28</strong></td>
<td><strong>Salon VI</strong></td>
</tr>
<tr>
<td></td>
<td>Fluid Physics 8 (C27)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Physical Science Overview, Informatics and KIBO Facilities (C28)</td>
<td></td>
</tr>
<tr>
<td>12:00 pm – 7:00 pm (optional tour/ independent activities)</td>
<td>Free Afternoon</td>
<td>n/a</td>
</tr>
<tr>
<td></td>
<td><strong>Optional Tour to NASA Kennedy Space Center</strong></td>
<td>n/a</td>
</tr>
<tr>
<td>7:30 pm – 9:30 pm</td>
<td>ASGSR Student Mixer (sponsored by CASIS)</td>
<td>International Foyer/ Upper Pool Deck</td>
</tr>
</tbody>
</table>

*NASA Kennedy Space Center Tour Logistics:*
- Tour limited to pre-registered participants with a ticket; all participants will need to bring their passport/government issued ID (driver’s license, etc.)
- Load chartered buses between 12:30-1:00 pm (Convention Entrance – Grand Foyer)
- Buses will depart Hilton Lake Buena Vista promptly at 1:00 pm
- Tour NASA Kennedy Space Center Complex from 2:00-6:00 pm
- Depart NASA KSC at 6:00 pm for return to Hilton Lake Buena Vista (7:00 pm arrival)
<table>
<thead>
<tr>
<th>Time</th>
<th>Event</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>7:00 am – 5:00 pm</td>
<td>Registration Open</td>
<td>East Registration</td>
</tr>
<tr>
<td>7:00 am – 8:30 am</td>
<td>Continental Breakfast</td>
<td>International Foyer</td>
</tr>
<tr>
<td>8:00 am – 5:00 pm</td>
<td>Exhibits – All Day</td>
<td>Center</td>
</tr>
<tr>
<td>8:00 am – 5:00 pm</td>
<td>Investigator and Student Posters – All Day</td>
<td>South</td>
</tr>
<tr>
<td>8:00 am – 9:00 am</td>
<td><strong>Information Session V</strong>: Introduction to Physical and Life Science Microgravity Research</td>
<td>Salon V</td>
</tr>
<tr>
<td>9:00 am – 10:00 am</td>
<td><strong>Concurrent Sessions 29-33</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Gravitational and Space Research Education Programs (C29)</td>
<td>Salon I-IV</td>
</tr>
<tr>
<td></td>
<td>Invertebrates (C30)</td>
<td>Salon VI</td>
</tr>
<tr>
<td></td>
<td>Fundamental Physics 3 - Dusty Plasmas (Part 1) (C31)</td>
<td>Salon VII</td>
</tr>
<tr>
<td></td>
<td>Biophysics 2 (C32)</td>
<td>Crystal</td>
</tr>
<tr>
<td></td>
<td>Combustion 1 - Droplet Combustion (Part 1) (C33)</td>
<td>Salon VIII</td>
</tr>
<tr>
<td>10:00 am – 10:30 am</td>
<td><strong>Morning Break Service</strong></td>
<td>Grand Foyer</td>
</tr>
<tr>
<td>10:30 am – 12:00 pm</td>
<td><strong>Concurrent Sessions 34-38</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Plants 3 (C34)</td>
<td>Salon V</td>
</tr>
<tr>
<td></td>
<td>Vertebrates 3 (C35)</td>
<td>Salon VI</td>
</tr>
<tr>
<td></td>
<td>Fluid Physics 9 (C36)</td>
<td>Crystal</td>
</tr>
<tr>
<td></td>
<td>Fundamental Physics 4 - Cold Atom Laboratory (C37)</td>
<td>Salon VII</td>
</tr>
<tr>
<td></td>
<td>Combustion 2 - Combustion Phenomena in Microgravity (C38)</td>
<td>Salon VIII</td>
</tr>
<tr>
<td>12:00 pm – 2:00 pm</td>
<td><strong>Lunch (on your own)</strong></td>
<td>n/a</td>
</tr>
<tr>
<td></td>
<td><strong>ASGSR External &amp; Strategic Affairs Committee Meeting (12:00-1:00 pm)</strong></td>
<td>Narcissus</td>
</tr>
<tr>
<td></td>
<td><strong>ASGSR Communication Committee Meeting (12:00-1:00 pm)</strong></td>
<td>Orange Blossom</td>
</tr>
<tr>
<td></td>
<td><strong>Workshop V</strong>: Microscopes on the ISS (12:30-2:00 pm)</td>
<td>Salon I-IV</td>
</tr>
<tr>
<td>2:00 pm – 3:30 pm</td>
<td><strong>Concurrent Sessions 39-43</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Enabling Technology 2 (C39)</td>
<td>Salon V</td>
</tr>
<tr>
<td></td>
<td>Vertebrates 4 (C40)</td>
<td>Salon VI</td>
</tr>
<tr>
<td></td>
<td>Fundamental Physics 5 - Atom Interferometry (C41)</td>
<td>Salon VII</td>
</tr>
<tr>
<td></td>
<td>Combustion 3 - Microgravity Fire Safety and Flammability (Part 1) (C42)</td>
<td>Salon VIII</td>
</tr>
<tr>
<td></td>
<td>Complex Fluids 1 (C43)</td>
<td>Crystal</td>
</tr>
<tr>
<td>3:30 pm – 4:00 pm</td>
<td><strong>Afternoon Break Service</strong></td>
<td>Grand Foyer</td>
</tr>
<tr>
<td>4:00 pm – 5:00 pm</td>
<td><strong>Concurrent Sessions 44-48</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Enabling Technology 3 (C44)</td>
<td>Salon V</td>
</tr>
<tr>
<td></td>
<td>Vertebrates 5 (C45)</td>
<td>Salon VI</td>
</tr>
<tr>
<td></td>
<td>Fundamental Physics 6 - Dusty Plasmas (Part 2) (C46)</td>
<td>Salon VII</td>
</tr>
<tr>
<td></td>
<td>Combustion 4 - Microgravity Fire Safety and Flammability (Part 2) (C47)</td>
<td>Salon VIII</td>
</tr>
<tr>
<td></td>
<td>Complex Fluids 2 (C48)</td>
<td>Crystal</td>
</tr>
<tr>
<td>5:00 pm – 5:30 pm</td>
<td><strong>Information Session VI</strong>: CIR/FIR Facilities</td>
<td>Salon VII</td>
</tr>
</tbody>
</table>
## General Daily Schedule

### Thursday, November 7, 2013 (cont’d)

<table>
<thead>
<tr>
<th>Time</th>
<th>Event</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>6:00 pm – 7:00 pm</td>
<td><strong>ASGSR Mixer (Cash Bar)</strong></td>
<td>Grand Foyer</td>
</tr>
</tbody>
</table>
| 7:00 pm – 10:00 pm | **ASGSR Banquet and Awards Ceremony**  
Keynote Speaker: Astronaut Don Pettit (sponsored by Techshot) | Salon I-IV     |

### Friday, November 8, 2013

<table>
<thead>
<tr>
<th>Time</th>
<th>Event</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>7:00 am – 1:00 pm</td>
<td><strong>Registration Open</strong></td>
<td>East Registration</td>
</tr>
<tr>
<td>7:00 am – 8:30 am</td>
<td><strong>Continental Breakfast</strong></td>
<td>International Foyer</td>
</tr>
<tr>
<td>8:00 am – 12:00 pm</td>
<td><strong>Exhibits</strong></td>
<td>Center</td>
</tr>
<tr>
<td>8:00 am – 12:00 pm</td>
<td><strong>Investigator and Student Posters</strong></td>
<td>South</td>
</tr>
<tr>
<td>8:00 am – 10:00 am</td>
<td><strong>Concurrent Sessions 49-51</strong></td>
<td>Salon VI</td>
</tr>
<tr>
<td></td>
<td>Fluid Physics 10 (C49)</td>
<td>Salon VI</td>
</tr>
<tr>
<td></td>
<td>Complex Fluids 3 (C50)</td>
<td>Salon VII</td>
</tr>
<tr>
<td></td>
<td>Combustion 5 - Droplet Combustion (Part 2) (C51)</td>
<td>Salon VIII</td>
</tr>
</tbody>
</table>
| 8:30 am – 10:00 am | **Information Session VII: Space Life and Physical Science Hot Topics**  
Status/Updates | Salon I-IV     |
| 10:00 am – 10:30 am | **Morning Break Service**                                             | Grand Foyer    |
| 10:30 am – 12:00 pm | **Workshop VI: NASA Life Sciences Proposal Workshop**                 | Salon I-IV     |
| 10:30 am – 12:00 pm | **Workshop VII: Open Source Physical Science Workshop**               | Salon V        |
| 10:30 am – 12:00 pm | **Concurrent Session 52**                                             | Salon VII      |
| 12:00 pm       | **Official Close of ASGSR/ISPS Meeting**                              |                |
| 12:00 pm – 4:00 pm | **Exhibit/Poster Break-down**                                         |                |

### Post-Meeting Activities:

#### Friday, November 8, 2013 – Post-meeting activities

<table>
<thead>
<tr>
<th>Time</th>
<th>Event</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>12:00 pm – 2:00 pm</td>
<td><strong>ASGSR Governing Board (lunch provided)</strong></td>
<td>Azalea /Begonia</td>
</tr>
<tr>
<td>12:00 pm – 2:00 pm</td>
<td><strong>AIAA Microgravity Processes Technical Committee Meeting (lunch provided)</strong></td>
<td>Poinsettia/Quince</td>
</tr>
<tr>
<td>12:00 pm – 2:00 pm</td>
<td><strong>Complex Matter Workshop (by invitation; lunch on your own)</strong></td>
<td>Kahili/Lily</td>
</tr>
<tr>
<td>2:00 pm – 5:00 pm</td>
<td><strong>International Microgravity Strategic Planning Group (IMSPG) kick-off (by invitation)</strong></td>
<td>Narcissus/Orange</td>
</tr>
</tbody>
</table>

#### Saturday, November 9, 2013 – Post-meeting activities

<table>
<thead>
<tr>
<th>Time</th>
<th>Event</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>8:30 am – 3:00 pm</td>
<td><strong>International Microgravity Strategic Planning Group (IMSPG) cont’d</strong></td>
<td>Narcissus/Orange</td>
</tr>
</tbody>
</table>
## Detailed Daily Schedule

### Sunday, November 3, 2013

<table>
<thead>
<tr>
<th>Time</th>
<th>Activity</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>12:00 pm–5:00 pm</td>
<td>Registration Open</td>
<td>East Registration</td>
</tr>
<tr>
<td>12:00 pm–5:00 pm</td>
<td>Set up – Exhibitors</td>
<td>Center</td>
</tr>
<tr>
<td>12:00 pm–5:00 pm</td>
<td>Set up – Investigator and Student Posters</td>
<td>South</td>
</tr>
<tr>
<td>4:00 pm–6:00 pm</td>
<td>ASGSR Governing Board Meeting</td>
<td>Azalea / Begonia</td>
</tr>
</tbody>
</table>

### Monday, November 4, 2013

<table>
<thead>
<tr>
<th>Time</th>
<th>Activity</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>7:00 am–5:00 pm</td>
<td>Registration Open</td>
<td>East Registration</td>
</tr>
<tr>
<td>7:00–8:30 am</td>
<td>Continental Breakfast</td>
<td>Int’l Foyer</td>
</tr>
<tr>
<td>8:00 am–5:00 pm</td>
<td>Exhibits – All Day</td>
<td>Center</td>
</tr>
<tr>
<td>8:00 am–5:00 pm</td>
<td>Investigator and Student Posters – All Day</td>
<td>South</td>
</tr>
<tr>
<td>8:30 am–12:00 pm</td>
<td><strong>Welcome and Opening Remarks, Plenary Session: International Space Agency</strong>&lt;br&gt;Program Updates and Congressional Perspectives&lt;br&gt;Chair: Dr. Joseph Tash, University of Kansas Medical Center</td>
<td>Salon I-IV</td>
</tr>
<tr>
<td>8:00-8:30 am</td>
<td>Dr. Joseph Tash, ASGSR President, Univ of Kansas Medical Center&lt;br&gt;Dr. Fran Chiaramonte, ISPS Chair, NASA Headquarters</td>
<td>Salon I-IV</td>
</tr>
<tr>
<td>8:30-9:00 am</td>
<td>Dr. Martin Zell, European Space Agency</td>
<td>Salon I-IV</td>
</tr>
<tr>
<td>9:00-9:30 am</td>
<td>Dr. Takayanagi, Japanese Space Agency</td>
<td>Salon I-IV</td>
</tr>
<tr>
<td>9:30-10:00 am</td>
<td>Dr. Gu Yidong, Chinese Space Agency</td>
<td>Salon I-IV</td>
</tr>
<tr>
<td>10:00-10:30 am</td>
<td><strong>Break (part of Morning Break Service)</strong></td>
<td>Salon I-IV</td>
</tr>
<tr>
<td>10:30-11:00 am</td>
<td>Dr. Ellen Stofan, NASA Chief Scientist</td>
<td>Salon I-IV</td>
</tr>
<tr>
<td>11:00-11:30 am</td>
<td>Dr. Marshall Porterfield, NASA Space Life and Physical Sciences Research and Applications Division</td>
<td>Salon I-IV</td>
</tr>
<tr>
<td>11:30-12:00 pm</td>
<td>Dr. Julie Robinson, International Space Station Chief Scientist</td>
<td>Salon I-IV</td>
</tr>
<tr>
<td>Invited</td>
<td>Ann Zulkosky, Senior Professional Staff, Senate Commerce, Science and Transportation Committee Representative, NASA Space Technology Mission Directorate</td>
<td>Salon I-IV</td>
</tr>
<tr>
<td>10:00–10:30 am</td>
<td>Morning Break Service</td>
<td>Grand Foyer</td>
</tr>
<tr>
<td>12:00–2:00 pm</td>
<td><strong>ASGSR Membership Committee Meeting (12:00-1:00 pm)</strong>&lt;br&gt;Chair: Nicole Rayl, geneLAB Project Manager, NASA Headquarters</td>
<td>Narcissus</td>
</tr>
<tr>
<td>12:00–2:00 pm</td>
<td><strong>ASGSR Meetings/Workshops Committee Meeting (12:00-1:00 pm)</strong>&lt;br&gt;Chair: Dr. Joseph Tash, University of Kansas Medical Center</td>
<td>Orange Blossom</td>
</tr>
<tr>
<td></td>
<td><strong>Workshop I: Drop Tower Workshop (1:00-2:00 pm) (page 43)</strong>&lt;br&gt;Chair/Organizer: David Urban, NASA Glenn Research Center</td>
<td>Salon V</td>
</tr>
<tr>
<td>2:00–3:30 pm</td>
<td><strong>Workshop II: CASIS – The ISS National Laboratory (page 43)</strong>&lt;br&gt;Chair/Organizer: Duane Ratliff, Chief Operating Officer, CASIS</td>
<td>Salon I-IV</td>
</tr>
<tr>
<td>2:00–3:30 pm</td>
<td><strong>Concurrent Session 1: Fluid Physics 1 (C1, pages 47-48)</strong>&lt;br&gt;Session Co-Chairs: Brian Motil and Henry Nahra, NASA Glenn Research Center</td>
<td>Salon VI</td>
</tr>
<tr>
<td>2:00–3:30 pm</td>
<td><strong>Concurrent Session 2: Fundamental Physics 1 – Atomic Clock Ensemble in Space (C2, pages 48-49)</strong>&lt;br&gt;Session Chair: Ulf Israelsson, NASA Jet Propulsion Laboratory</td>
<td>Salon VII</td>
</tr>
<tr>
<td>2:00–2:20 pm</td>
<td>[C1.1] Flow Boiling and Condensation Experiment (FBCE) for the International Space Station–Predictive Tools. Issam Mudawar, Purdue University.</td>
<td>Salon VII</td>
</tr>
<tr>
<td>2:40–3:00 pm</td>
<td>[C1.3] Single Bubble Dynamics under Microgravity Conditions. E. Aktinol, University of California, Los Angeles.</td>
<td>Salon VII</td>
</tr>
<tr>
<td>3:00–3:20 pm</td>
<td>[C1.4] CVB: The Constrained Vapor Bubble Capillary 40 mm Fin Experiment on the ISS. Peter C. Wayner, Jr., Rensselaer Polytechnic Institute.</td>
<td>Salon VII</td>
</tr>
<tr>
<td>2:00–3:30 pm</td>
<td><strong>Concurrent Session 2: Fundamental Physics 2 – Atomic Clock Ensemble in Space (C2, pages 48-49)</strong>&lt;br&gt;Session Chair: Ulf Israelsson, NASA Jet Propulsion Laboratory</td>
<td>Salon VII</td>
</tr>
<tr>
<td>2:00–2:20 pm</td>
<td>[C2.1] Atomic Sensors for Fundamental Physics Tests On-board the ISS. L. Cacciapuoti, European Space Agency.</td>
<td>Salon VII</td>
</tr>
</tbody>
</table>
### Detailed Daily Schedule

#### Monday, November 4, 2013

<table>
<thead>
<tr>
<th>Time</th>
<th>Session/Poster</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>2:20-2:40 pm</td>
<td>Concurrent Session 3: Materials Science 1 (C3, pages 49-51)</td>
<td>Salon VIII</td>
</tr>
<tr>
<td></td>
<td>Session Chair: Douglas Matson, Tufts University</td>
<td></td>
</tr>
<tr>
<td></td>
<td>[C3.1] Experimental Thermodiffusion and Diffusion Coefficients Measurements in Ternary Liquid Systems Aboard the International Space Station. Q. Galand, Microgravity Research Center, Université libre de Bruxelles.</td>
<td></td>
</tr>
<tr>
<td>2:40-3:00 pm</td>
<td>Concurrent Session 4: Microbes (C4, pages 52-53)</td>
<td>Crystal</td>
</tr>
<tr>
<td></td>
<td>Session Chair: Aaron Mills, University of Virginia</td>
<td></td>
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<tr>
<td></td>
<td>4:00-5:00 pm [C4.1] Whole Genome Re-sequencing of Low-Pressure (LP) Evolved Bacillus subtilis Identifies LP Adaptive Mutations. Samantha Marie Waters, University of Florida.</td>
<td>Crystal</td>
</tr>
<tr>
<td></td>
<td>4:00-4:15 pm [C4.2] Effect of Microgravity Emulation on Ammonia-Mediated Gene Expression and Cell Death in Giant Yeast Colonies. T.G. Hammond, Durham VA Medical Center, Duke University School of Medicine, Department of Veterans Affairs Office of Research &amp; Development, and George Washington School of Medicine.</td>
<td>Crystal</td>
</tr>
<tr>
<td>3:30–4:00 pm</td>
<td>Afternoon Break Service</td>
<td>Grand Foyer</td>
</tr>
<tr>
<td>3:00-3:20 pm</td>
<td>Concurrent Session 3: Microbiome (C3, pages 34-37)</td>
<td>Crystal</td>
</tr>
<tr>
<td></td>
<td>Session Chair: Elizabeth A. Blaber, NASA Ames Research Center</td>
<td>Crystal</td>
</tr>
<tr>
<td></td>
<td>2:40-3:00 pm [C3.2] Study of Gas Core Behavior of Passive Cycloidal Two-Phase Separator for Microgravity Applications. Yasuhiro Kamotani, Case Western Reserve University.</td>
<td>Crystal</td>
</tr>
<tr>
<td>4:00-5:00 pm</td>
<td>Concurrent Session 6: Fluid Physics 2 (C6, pages 54-55)</td>
<td>Salon VI</td>
</tr>
<tr>
<td></td>
<td>Session Chair: Peter Wayner, Jr., Rensselaer Polytechnic Institute</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4:00-4:15 pm [C6.1] Performance Studies of a DynaSwirl® Phase Separator for Space Applications. Xiongjun Wu, DynaFlow, Inc.</td>
<td>Salon VI</td>
</tr>
<tr>
<td></td>
<td>4:15-4:30 pm [C6.2] Study of Gas Core Behavior of Passive Cycloidal Two-Phase Separator for Microgravity Applications. Yasuhiro Kamotani, Case Western Reserve University.</td>
<td>Salon VI</td>
</tr>
<tr>
<td></td>
<td>4:30-4:45 pm [C6.3] Impact of Gravity on the Bubble-to-Pulse Transition in Packed Beds. P. Salgi, University of Houston.</td>
<td>Salon VI</td>
</tr>
<tr>
<td>4:00-5:00 pm</td>
<td>Concurrent Session 7: Fundamental Physics 2 – Space Optical Clocks (C7, pages 55-56)</td>
<td>Salon VII</td>
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<td></td>
<td>Session Chair: Nan Yu, NASA Jet Propulsion Laboratory</td>
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<tr>
<td></td>
<td>4:00-4:15 pm [C7.1] Optical Atomic Clocks for Space Applications. Nathan Hinkley, National Institute of Standards and Technology.</td>
<td>Salon VII</td>
</tr>
<tr>
<td></td>
<td>4:15-4:30 pm [C7.2] Impact of Microgravity on the Bubble-to-Pulse Transition in Packed Beds. P. Salgi, University of Houston.</td>
<td>Salon VII</td>
</tr>
<tr>
<td></td>
<td>4:45-5:00 pm [C7.4] Study of Gas Core Behavior of Passive Cycloidal Two-Phase Separator for Microgravity Applications. Yasuhiro Kamotani, Case Western Reserve University.</td>
<td>Salon VII</td>
</tr>
<tr>
<td></td>
<td>5:00-5:15 pm [C7.5] Development of Multiple Antibiotic Resistance in Opportunistic Pathogens Exposed to Spaceflight: the BRIC-18 mission to ISS. W.L. Nicholson, University of Florida.</td>
<td>Salon VII</td>
</tr>
</tbody>
</table>

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2013 ASGSR/ISPS Meeting
## Detailed Daily Schedule

### Monday, November 4, 2013

<table>
<thead>
<tr>
<th>Time</th>
<th>Event</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>4:40-5:00 pm</td>
<td>[C7.3] Towards a Miniature Optical Clock at JPL. Wade Rellergert, NASA Jet Propulsion Laboratory.</td>
<td></td>
</tr>
</tbody>
</table>
| 4:00–5:00 pm | Concurrent Session 8: Materials Science 2 (C8, pages 56-57)  
Session Chair: Martin Volz, NASA Marshall Space Flight Center | Salon VIII                          |
| 4:00-4:20 pm | [C8.1] X-RISE: X-ray Investigations under Space Environment. S. Klein, German Aerospace Center (DLR). |
| 5:00–5:30 pm | Information Session I: Research Opportunities for Materials & Fluids (page 45)  
Chair/Organizer: Fran Chiaramonte (NASA Headquarters) and Fred Kohl (NASA GRC) | Salon VI                            |
| 6:45–9:30 pm | Fireworks Reception at Disney’s Epcot (see page 6)  
6:45-7:00 pm| Load chartered buses between 6:45 – 7:00 pm (Convention Entrance – Grand Foyer) |
| 7:00 pm     | Buses depart Hilton Lake Buena Vista                                 |
| 7:00-7:20 pm | Transfer to Epcot; Guests escorted to Epcot World Showcase – France  |
| 7:30-8:30 pm | Epcot Reception on Terrace des Fleurs and Rue de Paris (cash bar)    |
| 9:30-10:00 pm | Return to Hilton on your own via complimentary Disney transportation services |

### Tuesday, November 5, 2013

<table>
<thead>
<tr>
<th>Time</th>
<th>Event</th>
<th>Location</th>
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<tbody>
<tr>
<td>7:00 am – 5:00 pm</td>
<td>Registration Open</td>
<td>East Registration</td>
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<tr>
<td>7:00–8:30 am</td>
<td>Continental Breakfast</td>
<td>Int’l Foyer</td>
</tr>
<tr>
<td>8:00 am–5:00 pm</td>
<td>Exhibits – All Day</td>
<td>Center</td>
</tr>
<tr>
<td>8:00 am–5:00 pm</td>
<td>Investigator and Student Posters – All Day</td>
<td>South</td>
</tr>
<tr>
<td>7:00 am–5:00 pm</td>
<td>Registration Open</td>
<td>East Registration</td>
</tr>
</tbody>
</table>
| 8:00–10:00 am | Concurrent Session 9: Fluid Physics 3 (C9, pages 58-59)  
Session Chair: Mohammad Kassemi, NASA Glenn Research Center | Salon VI                            |
| 8:00-8:20 am | [C9.1] Transition of Thermocapillary-driven Convection in a High-aspect-ratio Liquid Bridge under Zero Gravity. H. Kawasaki, Tokyo University of Science, Japan. |
| 8:20-8:40 am | [C9.2] Soret-Induced Instability of a Binary Mixture in Square Cavity Heated from Above. T.P. Lyubimova, Institute of Continuous Media Mechanics, Russia. |
| 8:40-9:00 am | [C9.3] On oscillatory flow induced by thermocapillary effect in full-zone liquid bridge. Kosuke Motegi, Tokyo University of Science, Japan. |
| 8:00–10:00 am | Concurrent Session 10: Materials Science 3 (C10, pages 59-60)  
Session Chair: Stefan Klein, German Aerospace Center (DLR) | Salon VII                            |
| 8:00-8:20 am | [C10.1] New materials processing under strong gravitational field. T. Mashimo, Institute of Pulsed Power Science, Japan. |
| 8:40-9:00 am | [C10.3] Effect of Convection on Primary Dendrites: Observations from Ground-based and Space Station Processed Samples. Surendra N. Tewari, Cleveland State University. |
| 9:00-9:20 am | [C10.4] Homogenous SiGe Crystal Growth Experiment in the International Space Station. Y. Arai, Institute of Space and Astronautical Science, JAXA. |
### Tuesday, November 5, 2013

<table>
<thead>
<tr>
<th>Time</th>
<th>Session/Session Chair/Co-Chairs</th>
<th>Location</th>
</tr>
</thead>
</table>
| 8:00–10:00 am| Concurrent Session 11: DECLIC 1 — Past, Present and Future (C11, pages 61-62)
Session Co-Chairs: Michael Hicks (NASA GRC) and Mark Lee (NASA Headquarters) | Salon V  |
| 8:00-8:20 am | [C11.1] DECLIC: A Facility Dedicated to The Study of Transparent Media Onboard the ISS. G. Pont, National Centre for Space Studies, France. |          |
| 8:20-8:40 am | [C11.2] DECLIC operations and ground segment, an effective way to operate a payload. H. Burger, National Centre for Space Studies, France. |          |
| 8:40-9:00 am | [C11.3] DECLIC: a look back at 4 years of operations. G. Pont, National Centre for Space Studies, France. |          |
| 9:40-10:00 am| [C11.6] DECLIC: operations plan for the future. B. Zappoli, National Centre for Space Studies, France. |          |
| 10:00–10:30 am| Morning Break Service                                                                          | Grand Foyer|
| 8:30 am–12:00 pm| Symposium I: Space Radiation — Risks, Research and Countermeasures (S1, pages 39-40) Chair: Dr. William Atwell, The Boeing Company | Salon I-IV|
| 9:11-9:47 am  | [S1.2] Heavy Ion Radiobiology: Central Nervous System and Immune System. Greg A. Nelson. Departments of Basic Science and Radiation Medicine, Loma Linda University, Loma Linda, California, USA. |          |
| 9:47-10:23 am | [S1.3] Heavy-Ion radiobiology: Cancer. Mary Helen Barcellos-Hoff, New York University School of Medicine, New York, New York, USA. |          |
| 10:23-10:48 am| Break (part of Morning Break Service)                                                          |          |
| 10:48-11:24 am| [S1.4] Biological Countermeasures of Space Radiation-induced Invasive Carcinomas in Mouse Models of Lung and Colon Cancer. Jerry W. Shay, University of Texas Southwestern Medical Center, Dallas, Texas, USA. |          |
| 11:24-12:00 pm| [S1.5] Physical and Biological Measurement of Crew Doses and Results from Mars. Cary Zeitlin, Southwest Research Institute, Boulder, Colorado, USA. |          |
| 10:30 am–12:00 pm| Concurrent Session 12: Fluid Physics 4 (C12, page 63)
Session Chair: Issam Mudawar, Purdue University                                           | Salon VI  |
| 10:30-10:50 am| [C12.1] Electrical Capacitance Volume Tomography for the Packed Bed Reactor ISS Flight Experiment. Q.M. Marashdeh, Tech4Imaging LLC. |          |
| 11:10-11:30 am| [C12.3] Purdue and North Carolina A&T Undergraduate Student Space Station Experiment Program. Steven H. Collicott. Purdue University. |          |
| 10:30 am–12:00 pm| Concurrent Session 13: Materials Science 4 (C13, pages 63-65)
Session Chair: Ken Kelton, Washington University St. Louis                               | Salon VII |
| 11:10-11:30 am| [C13.3] Dendrite Growth Kinetics of D2 Tool Steel Undercooled Melts. J. Valloton, University of Alberta, DLR. |          |
| 10:30 am–12:00 pm| Concurrent Session 14: DECLIC 2 – Near-Critical Fluids Phenomena (C14, pages 65-66)
Session Chair: Inseob Hahn, NASA Jet Propulsion Laboratory                               | Salon V  |
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<tr>
<th>Time</th>
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<tbody>
<tr>
<td>12:00–2:00 pm</td>
<td>Lunch (on your own)</td>
<td>n/a</td>
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<tr>
<td>2:00–3:30 pm</td>
<td>ASGSR Education and Outreach Committee Meeting (12:00-1:00 pm)</td>
<td>Salon I-IV</td>
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<td>Chair: Kimberly Slater, CSS-Dynamac</td>
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<tr>
<td>2:00–2:15 pm</td>
<td>Information Session II: Market Driven Space Research (12:00-1:00 pm) (page 45)</td>
<td>Salon I-IV</td>
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<tr>
<td></td>
<td>Chair/Organizer: Tony Gannon, Space Florida</td>
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<tr>
<td>2:15–2:30 pm</td>
<td>ASGSR Journal Committee Meeting (1:00-2:00 pm)</td>
<td>Orange Blossom</td>
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<td>Chair/Organizer: Dr. Anna-Lisa Paul, University of Florida</td>
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<tr>
<td>2:30–2:45 pm</td>
<td>Workshop III: Fluids for Biology Workshop (1:00-2:00 pm) (page 43)</td>
<td>Salon VI</td>
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<td>Chair/Organizer: Brain Motil, NASA Glenn Research Center</td>
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<tr>
<td>2:00–3:30 pm</td>
<td>Concurrent Session 15: Enabling Technology 1 (C15, pages 67-69)</td>
<td>Salon VIII</td>
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<td>Session Chair: Sidney Sun, NASA Ames Research Center</td>
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<tr>
<td>2:00–2:15 pm</td>
<td>[C15.1] Considerations for Planning Rodent Research on the International Space Station (ISS).</td>
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<tr>
<td>3:00–3:15 pm</td>
<td>[C15.5] Current Trends in High Throughput Methods for In-Situ Space Research. Fathi Karouia, NASA Ames Research Center, University of California San Francisco.</td>
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</tr>
<tr>
<td>3:15–3:30 pm</td>
<td>[C15.6] Gene Expression Measurement Module (GEMM) - the door to high-throughput in-situ analyses of biological systems in space. Andrew Pohorille, NASA ARC, UCSD.</td>
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<tr>
<td>2:00–3:30 pm</td>
<td>Concurrent Session 16: Plants 1 (C16, pages 69-71)</td>
<td>Salon V</td>
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<td>Session Chair: Robert Ferl, University of Florida</td>
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<tr>
<td>2:15–2:30 pm</td>
<td>[C16.2] BRIC 17: Capturing Plant Co²⁺ and Hypoxic Signaling Networks Aboard the ISS. Sarah Swanson, University of Wisconsin.</td>
<td></td>
</tr>
<tr>
<td>2:45–3:00 pm</td>
<td>[C16.4] Long Term Exposure to Microgravity Triggers the Transcriptional Reprogramming of Cell Wall-related Genes in Arabidopsis. Taegun Kwon, The Samuel Roberts Noble Foundation.</td>
<td></td>
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<tr>
<td>3:00–3:15 pm</td>
<td>[C16.5] Plant Signaling in Microgravity. Imara Perera, North Carolina State University.</td>
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<tr>
<td>2:00–3:30 pm</td>
<td>Concurrent Session 17: Fluid Physics 5 (C17, pages 71-72)</td>
<td>Salon VI</td>
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<td>Session Chair: Jeffrey Marchetta, University of Memphis</td>
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<tr>
<td>2:00–2:20 pm</td>
<td>[C17.1] Recent advances in modeling particle accumulation in periodic thermocapillary waves. Hendrik Kuhlmann, Vienna University of Technology, Vienna, Austria.</td>
<td></td>
</tr>
<tr>
<td>2:20–2:40 pm</td>
<td>[C17.2] Correlation between dynamics surface deformations and particle accumulation structure (PAS) in HZ Liquid Bridge. Mizuki Suzuki, Tokyo University of Science, Japan.</td>
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</tbody>
</table>
## Detailed Daily Schedule

**Tuesday, November 5, 2013**

<table>
<thead>
<tr>
<th>Time</th>
<th>Session</th>
<th>Location</th>
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<tbody>
<tr>
<td>3:00–3:20 pm</td>
<td>[C17.4] Tangential Vibration Effect on Liquid-Gas (Liquid-Vapor) Interface Shape at Different Gravity Levels. Tatyana Lyubimova, Institute of Continuous Media Mechanics, Perm State University, Russia.</td>
<td>Salon VII</td>
</tr>
</tbody>
</table>
| 3:00–3:30 pm  | **Concurrent Session 18: Materials Science 5 (C18, pages 72-74)**  
Session Chair: Jonghyun Lee, University of Massachusetts-Amherst |                                  |
| 2:00–2:20 pm  | [C18.1] Thermophysical Property Measurements Under Reduced Gravity Conditions: Status of the ThermoLab-ISS and ThermoProp Projects. Hans J. Fecht, Universität Ulm, Institute of Micro and Nanomaterials, Germany. |                                  |
| 2:20–2:40 pm  | [C18.2] Preparation of Thermoanalytical Experiments on Liquid Metals for Processing on the ISS. R. K. Wunderlich, Universität Ulm, Institute of Micro and Nanomaterials, Germany. |                                  |
| 2:40–3:00 pm  | [C18.3] Thermophysical properties of highly doped Si<sub>1-x</sub>Ge<sub>x</sub> alloys under µg conditions. Yuansu Luo, I. Physics Institute, University Göttingen, Germany. |                                  |
| 2:00–3:30 pm  | **Concurrent Session 19: Biophysics 1 (C19, pages, 74-75)**  
Session Chair: Theresa Miller, NASA | Crystal                          |
| 2:20–2:40 pm  | [C19.2] Growth Rate Dispersion, a Predictive Indicator for Biological Crystal Samples that Improve in Microgravity. Edward Snell, Hauptman-Woodward Medical Research Institute, Department of Structural Biology, SUNY Buffalo. |                                 |
| 2:40–3:00 pm  | [C19.3] Microgravity Protein Crystallization Studies. Larry DeLucas, Center for Structural Biology, University of Alabama at Birmingham. |                                 |
| 3:00–3:30 pm  | Afternoon Break Service  
Grand Foyer                          |                                 |
| 3:30–6:30 pm  | DECLIC Team Meeting (by invitation)  
Poinsettia/Quince                          |                                 |
| 4:00–5:00 pm  | **Concurrent Session 20: Vertebrates 2 (C20, pages 76-77)**  
Session Chair: April Ronca, NASA ARC, Wake Forest University School of Medicine | Salon VIII                      |
| 4:00–4:15 pm  | [C20.1] Decreased Mortality Rate of Mice Challenged with Serially in Vitro Passaged of Starved Pseudomonas aeruginosa Strain. Tesfaye Belay, Bluefield State College. |                                 |
| 4:30–4:45 pm  | [C20.3] X-Ray Movie Visualization for Differential Thresholds of Mouse Adaptation to Low Gravities. Yasuhiro Kumei, Tokyo Medical and Dental University, Japan. |                                 |
| 4:00–5:00 pm  | **Concurrent Session 21: Plants 2 (C21, pages 77-78)**  
Session Chair: Melanie Correll, University of Florida | Salon V                          |
| 4:45–5:00 pm  | [C21.4] Long-Range Systemic Stress Signaling in Plants by Ca<sup>2+</sup> Waves. Won-Gyu Choi, University of Wisconsin. |                                 |
| 4:00–5:00 pm  | **Concurrent Session 22: Fluids Physics 6 (C22, pages 78-79)**  
Session Chair: Robert Greene, NASA Glenn Research Center | Salon VI                          |
| 4:00–4:20 pm  | [C22.1] Analysis of the Critical Marangoni Number Dependence with the Characteristic Length in High Prandtl Number Fluid. Shinichi Yoda, ISAS/JAXA. |                                 |
## Detailed Daily Schedule

**Tuesday, November 5, 2013**

<table>
<thead>
<tr>
<th>Time</th>
<th>Session / Topic</th>
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<tbody>
<tr>
<td>4:20-4:40 pm</td>
<td>[C22.2] Recent Measurement of Soret Coefficients for Ternary Hydrocarbon Mixture on Board ISS. M.Z. Saghir, Ryerson University, Toronto, Canada.</td>
</tr>
<tr>
<td>4:40-5:00 pm</td>
<td>[C22.3] Review of ground and microgravity measurements of diffusion and Soret coefficients in multicomponent hydrocarbons. Stefan Van Vaerenbergh, Microgravity Research Center, Université libre de Bruxelles.</td>
</tr>
<tr>
<td>4:00–5:00 pm</td>
<td><strong>Concurrent Session 23: Materials Science 6 (C23, page 79)</strong> Session Chair: James P. Downey, NASA Glenn Research Center</td>
</tr>
<tr>
<td>4:00–5:00 pm</td>
<td><strong>Concurrent Session 24: Acceleration Measurements/Suborbital Flights (C24, pages 79-80)</strong> Session Chair: Kenol Jules, NASA Glenn Research Center</td>
</tr>
<tr>
<td>5:00–5:30 pm</td>
<td><strong>Information Session III: Express Rack Facility (page 45)</strong> Chair/Organizer: Robert Corban, NASA Glenn Research Center</td>
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<td></td>
<td><strong>Information Session IV: Microgravity Science Glovebox (page 45)</strong> Chair/Organizer: Robert Corban, NASA Glenn Research Center</td>
</tr>
<tr>
<td>6:00–9:00 pm</td>
<td><strong>Reception &amp; Official Investigator and Student Poster Session</strong> 6:00 – 7:30 pm: Even numbered posters presented 7:30 – 9:00 pm: Odd numbered posters presented</td>
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<td><em>See pages 118-144 for full abstracts</em></td>
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</tbody>
</table>

### INVESTIGATOR POSTERS:

**IP.1** Fatty Acid Content and Microviscosity in Pea Seedlings Plasmalemma Under Clinorotation. Elizabeth Kordyum, Institute of Botany, Nat. Acad. Sci. of Ukraine, Kiev, Ukraine.

**IP.2** Ankle Plantar-flexion is Essential for Mobilization of Soleus during Cycling and Weight-lifting Exercise in Human. Hirooki Okabe, Kokushikan University, Tokyo, Japan.

**IP.3** Role(s) of Neural Factor(s) in the Unloading-related Atrophy of Ankle Extensors in Rats. Takashi Ohira, Osaka Univ., Japan.

**IP.4** Gravitational Potentials and Dynamics Of Galaxies Against The Cosmological Background. Maxim Eingorn, North Carolina Central University.

**IP.5** Contractile Mode and Work Volume Influences on Lactate and Testosterone Values from Flywheel-based Exercise. John Caruso, The University of Tulsa.


**IP.7** Vibration Isolation Platform for Microgravity Research Experiments. Scott Green, Controlled Dynamics Inc., Huntington Beach, California.

**IP.8** Dynamic Analysis of the Center of Gravity Using Mouse and Study of Motion Efficiency. Tomomi Kawasaki, Japan Aerospace Exploration Agency.

**IP.9** Preparations for Advanced Plant Experiments (APEX) 02-1 in space using the Advanced Biological Research System. Jin Nakashima, The Samuel Roberts Noble Foundation, Ardmore, Oklahoma.

**IP.10** Dust Acoustic Instability in a Strongly Coupled Dusty Plasma. Marlene Rosenberg, University of California, San Diego.

**IP.11** ESA’s Atmosphere-Space Interactions Monitor (ASIM) for the ISS. Astrid Orr, ESA/ESTEC, The Netherlands.


**IP.13** ESA’s SOLAR Observatory on the ISS. Astrid Orr, ESA/ESTEC, The Netherlands.

**IP.14** ESA’s Planet Precursors Experiment for the ISS: “ICAPS.” Astrid Orr, ESA/ESTEC, The Netherlands.


**IP.16** Antioxidant supplement for prevention of capillary regression and inhibition of thrombospondin-1 in unloading-induced atrophied muscle. Hidemi Fujino, Kobe University, Japan.
### Detailed Daily Schedule

#### Tuesday, November 5, 2013

**IP.17** ER Alpha and VDR Polymorphisms Modify Musculoskeletal in Responses to Exercise and Food Intake. Hiroyo Kondo, Nagoya Women’s University, Japan.

**IP.18** Development of Multiple Antibiotic Resistance in Bacillus subtilis Cells Exposed to Simulated Microgravity. Patricia Fajardo-Cavazos, University of Florida, Space Life Sciences Laboratory.

**IP.19** Profiling Gene Expression in Brassica Roots at High Spatial and Temporal Resolution. Myoung Ryoul Park, University of Louisiana, Lafayette, Louisiana.

**IP.20** Drosophila Habitat with Flight Heritage Developed to Support Research On-board ISS. Matthew Lera, NASA Ames Research Center/Lockheed Martin.

**IP.21** Atomistic simulation of ceria nanoparticles to counter radiation induced damages. Sudipta Seal, Univ. of Central Florida.


**IP.23** Engineered Rare Earth Nanoparticles for Alleviating Radiation Induced Injury. Sudipta Seal, University of Central Florida.


**IP.25** Soft Matter, Colloids and Granular Matter research and instruments in ESA’s ELIPS programme. Olivier Minster, Utilisation and Astronaut Support Department, Human Spaceflight and Operations Directorate, European Space Agency.

**IP.26** Red Light Effects on Blue-Light-Based Phototropism in Roots and Hypocotyls. Katherine Millar, National Center for Natural Products Research, University of Mississippi.


**IP.30** Prenatal exposure to either increased gravity or prenatal stress programs common, sexually dimorphic effects on adult bodyweight. April E. Ronca, NASA Ames Research Center, Wake Forest University School of Medicine.


**IP.32** EML On Board the International Space Station. Daniela Voss, HESpace B.V. for European Space Agency, The Netherlands.

**IP.33** Directional Solidification Experiments using the Materials Science Laboratory on the ISS. Daniela Voss, HESpace B.V. for European Space Agency, The Netherlands.


**IP.35** The TRANSPARENT ALLOYS instrument for in-situ monitoring of solidification processes on board the ISS. Daniela Voss, HESpace B.V. for European Space Agency, The Netherlands.


**IP.37** Measurements of Density and Structure of Alloys Liquids by Levitation Technique. Masahito Watanabe, Gakushuin University, Japan.

**IP.38** Dusty Plasma Physics Facility (DPPF). John Goree, The University of Iowa, Iowa City, Iowa.

**IP.39** Influence of Heater Thermal Capacity on Characteristics of Single Bubble Pool Boiling. Jian-Fu Zhao, Key Laboratory of Microgravity (National Microgravity Laboratory)/CAS, Institute of Mechanics, Chinese Academy of Sciences, Beijing, China.

**IP.40** The Effects on Gene Expression on Human Hair and Mice Skin by Spaceflight. Masahiro Terada, JAXA.

**IP.41** Microflow1: First Flow Cytometric Analysis On The ISS. Lucchino Cohen, Canadian Space Agency.

**IP.42** Enhanced Capillary Height of Wetting Liquids in Reduced Gravitational Shielding under Microgravity Conditions. Ioannis Gkigkitzis, East Carolina University, Greenville, North Carolina.

### STUDENT POSTERS:

**SP.1** Differential Signal Expression of Arabidopsis GFP Reporter Gene Constructs on Orbit. Eric R. Schultz, Program in Plant Molecular and Cellular Biology, University of Florida, Gainesville, Florida.

**SP.2** Disruption of Cell Growth and Proliferation Induced by Simulated Microgravity on Synchronic Plant Cell Cultures. Khaled Youssef, DESC (Dutch Experiment Support Center), VU University Medical Center & Academic Centre for Dentistry Amsterdam.

**SP.3** A Gradient of Extracellular Nucleotides Directs Polarization in Early Growth and Development of Ceratopteris Spores. Ashley E. Cannon, The University of Texas at Austin, Texas.

**SP.4** Gravitropic curvature and auxin transport as a function of reorientation of Brassica roots. Chitra Pandita, Biology Department, University of Louisiana at Lafayette, Lafayette, Louisiana.
<table>
<thead>
<tr>
<th>Time</th>
<th>Session</th>
<th>Title</th>
<th>Presenter(s)</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>SP.5</td>
<td>An Extraterrestrial Approach to Gene Discovery.</td>
<td>Natasha J. Sng, Program in Plant Molecular and Cellular Biology, University of Florida, Gainesville, Florida.</td>
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<tr>
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<td>SP.6</td>
<td>Drying Without Dying: Drought resistance in Resurrection Fern.</td>
<td>Susan P. John, Department of Biology, University of Louisiana at Lafayette, Lafayette, Louisiana.</td>
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<tr>
<td></td>
<td>SP.7</td>
<td>Differential Gene Expression in Brassica rapa Roots After Reorientation and Clinorotation.</td>
<td>Andrea A. Edge, University of Louisiana at Lafayette, Lafayette, Louisiana.</td>
</tr>
<tr>
<td></td>
<td>SP.10</td>
<td>Quantitative Analysis of Arabidopsis Root Growth in Microgravity.</td>
<td>Kalyani S Joshi, Department of Plant and Microbial Biology, North Carolina State University, Raleigh, North Carolina.</td>
</tr>
<tr>
<td></td>
<td>SP.12</td>
<td>Metabolic Regulation of Contractile Properties, Associated with Mechanical and/or Neural Activities, in Rat Soleus.</td>
<td>Tomotaka Ohira, Grad. Sch. Health Sci., Toyohashi SOZO University, Japan.</td>
</tr>
<tr>
<td></td>
<td>SP.13</td>
<td>Effect of Myostatin Inhibition and Microgravity on L5 Lumbar Vertebrae Trabecular Bone Microarchitecture in Mice.</td>
<td>Stefanie M. Gonzalez, Department of Aerospace Engineering Sciences, Bioastronautics University of Colorado Boulder, Boulder, Colorado.</td>
</tr>
<tr>
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<td>SP.14</td>
<td>Finding Their Way in Space: An Alternative Strategy Improves Navigation Performance in Otoconia-Deficient Mice.</td>
<td>Ryan E. Harvey, Department of Psychology, Indiana University-Purdue University, Fort Wayne, Indiana.</td>
</tr>
<tr>
<td></td>
<td>SP.15</td>
<td>Comparison between Botulinum Toxin-Induced Muscle Paralysis and Hindlimb Unloading as Disuse Models.</td>
<td>Rachel Ellman, Center for Advanced Orthopaedic Studies, Beth Israel Deaconess Medical Center and Harvard Medical School, Boston, Massachusetts; Health Sciences and Technology, Massachusetts Institute of Technology, Cambridge, MA.</td>
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<tr>
<td></td>
<td>SP.16</td>
<td>Responses of Circulating MicroRNAs to Hindlimb Unloading and Reloading in Mice.</td>
<td>Miho Suzuki, Graduate School of Health Sciences, Toyohashi SOZO University, Japan.</td>
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<tr>
<td></td>
<td>SP.17</td>
<td>Responses of White Blood Cells to Leg Exercise with Lowered Blood Volume in Human.</td>
<td>Luna Ohira, Kansai University, Japan.</td>
</tr>
<tr>
<td></td>
<td>SP.20</td>
<td>Effects of Hindlimb Unloading on the Expressions of Angiopoietin1 and Tie-2 in Mouse Skeletal Muscles.</td>
<td>Akhiro Ikuta, Graduate School of Health Sciences, Toyohashi SOZO University, Japan.</td>
</tr>
<tr>
<td></td>
<td>SP.22</td>
<td>Microbiological Sampling Methods and Sanitization of Edible Plants Grown in Microgravity.</td>
<td>Charles H. Parrish II, Department of Biological and Agricultural Engineering, North Carolina State University, Raleigh, North Carolina.</td>
</tr>
<tr>
<td></td>
<td>SP.23</td>
<td>Microgravity Testing of an Active Compression-Decompression C.P.R. Device.</td>
<td>Keenan Johnson, Missouri University of Science and Technology.</td>
</tr>
<tr>
<td></td>
<td>SP.25</td>
<td>Examining the CO2 Dependent Relationships in a Membrane Aerated Biological Reactor Treating a Space-Based Wastewater.</td>
<td>Dylan Christenson, Texas Tech University, Lubbock, Texas.</td>
</tr>
<tr>
<td></td>
<td>SP.27</td>
<td>Electro-Hydrodynamic Manipulation of Bubbles in Microgravity.</td>
<td>Dana Qasem, Department of Chemical Engineering, New Jersey Institute of Technology, Newark, New Jersey.</td>
</tr>
<tr>
<td></td>
<td>SP.29</td>
<td>Numerical investigation for the thermocapillary flow observed in “Saturday-Morning-Science” conducted by Dr. Donald Pettit.</td>
<td>Takuya Yamamoto, Department of Materials Engineering Science, Osaka University, Japan.</td>
</tr>
<tr>
<td></td>
<td>SP.30</td>
<td>Reduced Gravity De-gassing of Perfluorohexane Coolant Using a Radial Membrane Contactor.</td>
<td>Danielle E. Weiland, Carthage College, Space Sciences.</td>
</tr>
<tr>
<td></td>
<td>SP.31</td>
<td>Effect of Oxygen in Liquid Zr on Surface Oscillation of Electrostatic Levitated Droplets.</td>
<td>Kenta Onodera, Department of Physics, Gakushuin University.</td>
</tr>
</tbody>
</table>
## Tuesday, November 5, 2013

<table>
<thead>
<tr>
<th>Session</th>
<th>Title</th>
<th>Speaker</th>
</tr>
</thead>
<tbody>
<tr>
<td>SP.32</td>
<td>Dropwise Condensation on a Radial Gradient Surface.</td>
<td>Ashley M. Macner, School of Chemical and Biomolecular Engineering, Cornell University, Ithaca, New York.</td>
</tr>
<tr>
<td>SP.33</td>
<td>Self-organization of Janus particles with chemical and geometrical anisotropy in semi-microgravity environment.</td>
<td>Chang-Hyung Choi, Department of Chemical Engineering, Chungnam National University, South Korea.</td>
</tr>
<tr>
<td>SP.34</td>
<td>Self-assembly of anisotropic Janus cylinders at oil-water interface.</td>
<td>Sung-Min Kang, Department of Chemical Engineering, Chungnam National University, South Korea.</td>
</tr>
<tr>
<td>SP.35</td>
<td>Effectivity of Xenon as Fire Suppressant under Microgravity Combustion Environment.</td>
<td>M.E.A. Fahd, Department of Mechanical Engineering, University of South Carolina, Columbia, South Carolina.</td>
</tr>
<tr>
<td>SP.36</td>
<td>Microgravity Experiment of Transition of Oscillatory Marangoni Convection in High Prandtl Number Liquid Column.</td>
<td>Kohei Omura, University of Tsukuba, Japan.</td>
</tr>
<tr>
<td>SP.37</td>
<td>Synchronization of dust acoustic waves under microgravity conditions.</td>
<td>W. D. Suranga Ruhunusiri, Dept of Physics and Astronomy, The University of Iowa, Iowa City, Iowa.</td>
</tr>
<tr>
<td>SP.39</td>
<td>Numerical Simulations of TLZ Crystal Growth Process of SiGe under Microgravity.</td>
<td>Keita Abe, Tohoku University, Japan.</td>
</tr>
<tr>
<td>SP.40</td>
<td>Novel Observations in Coarsening in Solid Liquid Mixtures: Results From the ISS.</td>
<td>John Thompson, Materials Science and Engineering, Northwestern University, Evanston, Illinois.</td>
</tr>
<tr>
<td>SP.41</td>
<td>Rapid Solidification of Levitated and Undercooled Ge-Sn Alloy Melt.</td>
<td>S. Yoneyama, School of Engineering, Shibaura Institute of Technology, Tokyo, Japan.</td>
</tr>
<tr>
<td>SP.42</td>
<td>Thermodynamic modeling for prediction of the solidification path in levitated FeCo alloys during space processing.</td>
<td>Justin Rodriguez, Mechanical Engineering Department, Tufts University.</td>
</tr>
</tbody>
</table>

## Wednesday, November 6, 2013

<table>
<thead>
<tr>
<th>Time</th>
<th>Event</th>
<th>Location</th>
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</thead>
<tbody>
<tr>
<td>7:00 am– 5:00 pm</td>
<td>Registration Open</td>
<td>East Registration</td>
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<tr>
<td>7:00–8:30 am</td>
<td>Continental Breakfast</td>
<td>Int’l Foyer</td>
</tr>
<tr>
<td>8:00 am–5:00 pm</td>
<td>Exhibits – All Day</td>
<td>Center</td>
</tr>
<tr>
<td>8:00 am–5:00 pm</td>
<td>Investigator and Student Posters – All Day</td>
<td>South</td>
</tr>
<tr>
<td>7:00 am–5:00 pm</td>
<td>Registration Open</td>
<td>East Registration</td>
</tr>
<tr>
<td>8:00–10:00 am</td>
<td>Symposium II: Suborbital Microgravity Research (S2, pages 41-42)</td>
<td>Salon I-IV</td>
</tr>
<tr>
<td>8:05–8:30 am</td>
<td>[S2.1] Space Biology in the Suborbital Realm.</td>
<td>Robert J. Ferl, University of Florida, Horticultural Sciences, Program in Plant Molecular and Cellular Biology and Interdisciplinary Center for Biotechnology Research, Gainesville, Florida, USA.</td>
</tr>
<tr>
<td>8:30–8:55 am</td>
<td>[S2.2] Next-Gen Suborbital Spaceflight Research and Education Opportunities.</td>
<td>S. Alan Stern, Southwest Research Institute, Boulder, Colorado, USA.</td>
</tr>
<tr>
<td>8:55–9:25 am</td>
<td>[S2.3] An Experimenter’s Experiences in Early Commercial Sub-orbital Spaceflight Launches.</td>
<td>Steven H. Collicott, School of Aeronautics and Astronautics, Purdue University, West Lafayette, Indiana, USA.</td>
</tr>
<tr>
<td>8:00–10:00 am</td>
<td>Concurrent Session 25: Fluid Physics 7 (C25, pages 81-82)</td>
<td>Salon VI</td>
</tr>
<tr>
<td>8:00-8:20 pm</td>
<td>[C25.1] Low Gravity Cryogenic Liquid Acquisition for Space Exploration.</td>
<td>David J. Chato, NASA Glenn Research Center.</td>
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<tr>
<td>Time</td>
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<td>Details</td>
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<tr>
<td>8:00–10:00 am</td>
<td>Concurrent Session 26: DECLIC 3 – Solidification Student (C26, pages 82-84)</td>
<td>Session Chair: James P. Downey, NASA Glenn Research Center</td>
</tr>
<tr>
<td>8:00-8:20 pm</td>
<td>[C26.1] 3D-Alloy Solidification in DECLIC Directional Solidification Insert: Live monitoring of microstructure formation in microgravity. Nathalie Bergeon, IM2NP, Aix-Marseille University, IM2NP, CNRS, Marseille, France.</td>
<td></td>
</tr>
<tr>
<td>8:20-8:40 pm</td>
<td>[C26.2] 3D-Alloy Solidification in DECLIC Directional Solidification Insert: Secondary instabilities observed in cellular growth. Nathalie Bergeon, IM2NP, Aix-Marseille University, IM2NP, CNRS, Marseille, France.</td>
<td></td>
</tr>
<tr>
<td>8:40-9:00 am</td>
<td>[C26.3] 3D-Alloy Solidification in DECLIC Directional Solidification Insert: Comparison 1g/µg Experiments, Influence of Convection. Bernard Billia, IM2NP, Aix-Marseille University, IM2NP, CNRS, Marseille, France.</td>
<td></td>
</tr>
<tr>
<td>9:00-9:20 am</td>
<td>[C26.4] 3D-alloy solidification in DECLIC Directional Solidification Insert: Numerical simulation of microgravity experiments. Damien Tourret, Department of Physics and Center for Interdisciplinary Research on Complex Systems, Northeastern University, Boston, Massachusetts, USA.</td>
<td></td>
</tr>
<tr>
<td>9:20-9:40 am</td>
<td>[C26.5] 3D-alloy solidification in DECLIC Directional Solidification Insert-R: Motivations for relight and SPADES/MISOL3D project perspectives. Alain Karma, Department of Physics and Center for Interdisciplinary Research on Complex Systems, Northeastern University, Boston, Massachusetts, USA.</td>
<td></td>
</tr>
<tr>
<td>9:40-10:00 am</td>
<td>[C26.6] 3D-alloy solidification in DECLIC Directional Solidification Insert: 1g-experiments on thin samples versus 3D-experiments in µg. Rohit Trivedi, Department of Materials Science &amp; Engineering, Iowa State University, Ames, Iowa, USA.</td>
<td></td>
</tr>
<tr>
<td>10:00–10:30 am</td>
<td>Morning Break Service</td>
<td>Grand Foyer</td>
</tr>
<tr>
<td>10:30–12:00 pm</td>
<td>Workshop IV: Education and Outreach Workshop (pages 43-44)</td>
<td>Chair/Organizer: Kim Slater (CSS-Dynamac) and Susan Mayo (NASA ISS Program Office)</td>
</tr>
<tr>
<td>10:30 am–12:00 pm</td>
<td>Concurrent Session 27: Fluid Physics 8 (C27, pages 85-86)</td>
<td>Session Chair: John McQuillen, NASA Glenn Research Center</td>
</tr>
<tr>
<td>10:30 am–12:00 pm</td>
<td>Concurrent Session 28: Physical Science Overview, Informatics and KIBO Facilities (C28, pages 86-87), Session Co-Chairs: Fran Chiaramonte and Sharon Conover (NASA HQ)</td>
<td>Salon V</td>
</tr>
<tr>
<td>11:10-11:30 am</td>
<td>[C28.3] International cooperation in physical sciences research in space in the framework of ESA’s ELIPS programme. Olivier Minster, Physical Sciences Unit, Utilisation and Astronaut Support Department, Human Spaceflight and Operations Directorate, European Space Agency.</td>
<td></td>
</tr>
</tbody>
</table>
## Detailed Daily Schedule

### Wednesday, November 6, 2013

<table>
<thead>
<tr>
<th>Time</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>11:45-12:00 pm</td>
<td>[C28.5] <em>Physical Science Informatics: Providing Open Source Access to ISS Science Data for the Benefit of All.</em> Benjamin L. Henrie, Dynetics Technical Services, Huntsville, Alabama, USA.</td>
</tr>
<tr>
<td>12:00 pm–7:00 pm</td>
<td>Free Afternoon</td>
</tr>
<tr>
<td>12:30 pm–7:00 pm</td>
<td>Optional Tour – NASA Kennedy Space Center (tour limited to pre-registered participants with a ticket)</td>
</tr>
<tr>
<td>12:30-1:00 pm</td>
<td>Load chartered buses between 6:45 – 7:00 pm (Convention Entrance – Grand Foyer); you may bring lunch onboard the bus</td>
</tr>
<tr>
<td>1:00 pm</td>
<td>Buses depart Hilton Lake Buena Vista</td>
</tr>
<tr>
<td>2:00-6:00 pm</td>
<td>Tour NASA Kennedy Space Center Complex</td>
</tr>
<tr>
<td>6:00 pm</td>
<td>Depart NASA Kennedy for return to Hilton Lake Buena Vista</td>
</tr>
<tr>
<td>7:30–9:30 pm</td>
<td>ASGSR Student Mixer (Sponsored by CASIS) Int’l Foyer/ Upper Pool Deck</td>
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### Thursday, November 7, 2013

<table>
<thead>
<tr>
<th>Time</th>
<th>Event</th>
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</thead>
<tbody>
<tr>
<td>7:00 am–5:00 pm</td>
<td>Registration Open East Registration</td>
</tr>
<tr>
<td>7:00–8:30 am</td>
<td>Continental Breakfast Int’l Foyer</td>
</tr>
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<td>8:00 am–5:00 pm</td>
<td>Exhibits – All Day Center</td>
</tr>
<tr>
<td>8:00 am–5:00 pm</td>
<td>Investigator and Student Posters – All Day South</td>
</tr>
<tr>
<td>8:00–9:00 am</td>
<td>Information Session V: Introduction to Physical and Life Science Microgravity Research (pages 45-46) Salon V</td>
</tr>
<tr>
<td>Session Chair/Organizer: Simon Gilroy (University of Wisconsin, Madison) and Mike Banish (University of Alabama at Huntsville)</td>
<td></td>
</tr>
<tr>
<td>9:00–10:00 am</td>
<td>Concurrent Session 29: Gravitational and Space Research Education Programs (C29, pages 88-89), Session Chair: Carol Carroll, NASA Ames Research Center Salon I-IV</td>
</tr>
<tr>
<td>9:15-9:30 am</td>
<td>[C29.2] <em>Student Near-Space Biological Research Using a Weather Balloon Platform.</em> Bernhard Beck-Winchatz, STEM Studies Department, DePaul Univ, Chicago, Illinois, USA.</td>
</tr>
<tr>
<td>9:45-10:00 am</td>
<td>[C29.4] <em>Bringing ISS to Students on Earth: Drop Studies of Capillary Flow.</em> Dennis P. Stocker, NASA Glenn Research Center.</td>
</tr>
<tr>
<td>9:00–10:00 am</td>
<td>Concurrent Session 30: Invertebrates (C30, pages 89-90), Session Chair: Jamie Foster, University of Florida Salon VI</td>
</tr>
<tr>
<td>9:15-9:30 am</td>
<td>[C30.2] <em>Acute Hypergravity Causes Altered Gene Expression, and Affects the Oxidative Stress Pathway in Drosophila.</em> Ravikumar Hosamani, Biomodel Performance and Behavior Laboratory, Space Bioscience Division, NASA Ames Research Center.</td>
</tr>
<tr>
<td>9:45-10:00 am</td>
<td>[C30.4] <em>Simulated Microgravity Alters Normal Bacteria-Induced Animal Development.</em> Jamie S. Foster, Department of Microbiology and Cell Science, University of Florida.</td>
</tr>
<tr>
<td>9:00–10:00 am</td>
<td>Concurrent Session 31: Fundamental Physics 3 – Dusty Plasmas (Part 1) (C31, pages 90-91), Session Chair: John Goree, University of Iowa Salon VII</td>
</tr>
<tr>
<td>9:00-9:30 am</td>
<td>[C31.1] <em>PK-4: Complex Plasmas onboard the ISS – The Next Generation.</em> Markus Thoma, University Giessen, Giessen, Germany.</td>
</tr>
</tbody>
</table>
### Detailed Daily Schedule

**Thursday, November 7, 2013**

<table>
<thead>
<tr>
<th>Time</th>
<th>Session</th>
</tr>
</thead>
<tbody>
<tr>
<td>9:45–10:00 am</td>
<td>[C31.3] <em>Developments for the Proposed International Space Station Experiment “PlasmaLab.”</em> Uwe Konopka, Auburn University, Physics Department, Auburn University, Alabama, USA.</td>
</tr>
<tr>
<td>9:00–10:00 am</td>
<td><strong>Concurrent Session 32: Biophysics 2 (C32, page 91)</strong>&lt;br&gt;Session Chair: Brian Motil, NASA Glenn Research Center&lt;br&gt;[C32.1] <em>A Roadmap for Sustainable Life Support.</em> Charles Quincy, NASA Kennedy Space Center.</td>
</tr>
<tr>
<td>9:00–10:00 am</td>
<td><strong>Concurrent Session 33: Combustion 1 – Droplet Combustion (Part 1)</strong>&lt;br&gt;(C33, pages 91-92), Session Chair: Michael Hicks, NASA Glenn Research Center&lt;br&gt;[C33.1] <em>A Ground-based Research for Fuel Droplet Cloud Combustion Experiment “Group Combustion” on KIBO/ISS.</em> Masato Mikami, Yamaguchi University, Japan.&lt;br&gt;[C33.2] <em>ISS Droplet Combustion Experiments - Uncertainties in Droplet Sizes and Burning Rates.</em> Benjamin D. Shaw, Mechanical and Aerospace Engineering Department, University of California, Davis, California, USA.&lt;br&gt;[C33.3] <em>Microgravity Combustion of Isolated Binary Alcohol/Alkane Droplets.</em> Patrizio Massoli, Istituto Motori – CNR, Consiglio Nazionale delle Ricerche, Naples, Italy.</td>
</tr>
<tr>
<td>10:00–10:30 am</td>
<td>Morning Break Service&lt;br&gt;Grand Foyer</td>
</tr>
<tr>
<td>10:30 am–12:00 pm</td>
<td><strong>Concurrent Session 34: Plants 3 (C34, pages 93-94)</strong>&lt;br&gt;Session Chair: Sarah Wyatt, Ohio University&lt;br&gt;[C34.1] <em>Operations of an experiment on plant tropisms on the International Space Station (Seedling Growth-1).</em> John Z. Kiss, Dept. Biology &amp; Graduate School, University of Mississippi, Oxford, Mississippi, USA.&lt;br&gt;[C34.2] <em>Differential Gene Expression in Brassica rapa Roots After Reorientation and Clinorotation.</em> Andrea A. Edge, University of Louisiana at Lafayette, Department of Biology, Lafayette, Louisiana, USA.&lt;br&gt;[C34.3] <em>Differential Signal Expression of Arabidopsis GFP Reporter Gene Constructs on Orbit.</em> Eric R. Schultz, Program in Plant Molecular and Cellular Biology, University of Florida, Gainesville, Florida, USA.&lt;br&gt;[C34.4] <em>Effect of Atmospheric Pressure on Wet Bulb Depression.</em> Raymond Wheeler, NASA Kennedy Space Center, Florida, USA.&lt;br&gt;[C34.5] <em>A Short Interval Hypergravity Exposure Affects Photosynthetic and Biochemical Indices in Wheat.</em> Pandit B. Vidyasagar, Biophysics laboratory, Department of Physics, University of Pune, Pune, India.</td>
</tr>
<tr>
<td>10:30 am–12:00 pm</td>
<td><strong>Concurrent Session 35: Vertebrates 3 (C35, pages 94-96)</strong>&lt;br&gt;Session Chair: Ruth Globus, NASA Ames Research Center&lt;br&gt;[C35.1] <em>Comparison between Botulinum Toxin-Induced Muscle Paralysis and Hindlimb Unloading as Disuse Models.</em> Rachel Ellman, Center for Advanced Orthopaedic Studies, Beth Israel Deaconess Medical Center and Harvard Medical School, Boston, MA; Health Sciences and Technology, Massachusetts Institute of Technology, Cambridge, MA, USA.&lt;br&gt;[C35.2] <em>Changes in Mice Calvaria Following Fifteen Days in Space.</em> Roshmi Bhattacharya, Department of Orthopedic Surgery, University of California San Diego, La Jolla, CA, USA.&lt;br&gt;[C35.3] <em>Effect of Myostatin Inhibition and Microgravity on L5 Lumbar Vertebrae Trabecular Bone Microarchitecture in Mice.</em> Stefanie M. Gonzalez, Department of Aerospace Engineering Sciences, Bioastronautics University of Colorado Boulder, CO, USA.&lt;br&gt;[C35.4] <em>Sex and Gender are Not Lost in Space.</em> Graham B.I. Scott, National Space Biomedical Research Institute; Center for Space Medicine, Baylor College of Medicine; Department of Molecular and Cellular Biology, Baylor College of Medicine, Houston, Texas, USA.</td>
</tr>
<tr>
<td>Time</td>
<td>Session</td>
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<tr>
<td>10:30 am–12:00 pm</td>
<td><strong>Concurrent Session 36: Fluid Physics 9 (C36, page 96)</strong>&lt;br&gt;Session Chair: Steven H. Collicott, Purdue University</td>
</tr>
<tr>
<td>10:30-10:50 am</td>
<td>[C36.1] The Capillary Channel Flow (CCF) experiments on the International Space Station. Michael E. Dreyer, Center for Applied Space Technology, Department of Fluid Mechanics, Faculty Production Engineering – Mechanical and Chemical Engineering, University of Bremen, Bremen, Germany.</td>
</tr>
<tr>
<td>10:30 am–12:00 pm</td>
<td><strong>Concurrent Session 37: Fundamental Physics 4 – Cold Atom Laboratory (C37, pages 96-98)</strong>, Session Chair: Mark C. Lee, NASA Headquarters</td>
</tr>
<tr>
<td>10:30-10:50 am</td>
<td>[C37.1] Interferometry with chip based atom lasers. Ernst M. Rasel for the QUANTUS Cooperation, QUEST, Institut für Quantenoptik, Leibniz Universität, Germany.</td>
</tr>
<tr>
<td>10:50-11:10 am</td>
<td>[C37.2] The Coolest Spot in the Universe: A Facility for Cold Atom Experiments Aboard the ISS. Robert J. Thompson, Jet Propulsion Laboratory, California Institute of Technology, Pasadena CA, USA.</td>
</tr>
<tr>
<td>11:10-11:30 am</td>
<td>[C37.3] Hybrid Magnetic and Optical Atom Chip Technology for Cold and Ultracold Matter Systems. Dana Z. Anderson, Department of Physics and JILA, University of Colorado, Boulder CO, USA.</td>
</tr>
<tr>
<td>11:45-12:00 pm</td>
<td>[C37.5] The Cold Atom Laboratory Mission Overview. Anita Sengupta, California Institute of Technology, Jet Propulsion laboratory, Pasadena, CA, USA.</td>
</tr>
<tr>
<td>10:30 am–12:00 pm</td>
<td><strong>Concurrent Session 38: Combustion 2 – Combustion Phenomena in Microgravity (C38, pages 98-99)</strong>, Session Chair: David Urban, NASA Glenn Research Center</td>
</tr>
<tr>
<td>10:50-11:10 am</td>
<td>[C38.2] E-Field: Electric Field Effects on Laminar Diffusion Flames. Jessy A. Tinajero, Department of Mechanical and Aerospace Engineering University of California, Irvine, California, USA.</td>
</tr>
<tr>
<td>12:00–2:00 pm</td>
<td><strong>ASGSR External &amp; Strategic Affairs Committee Meeting (12:00-1:00 pm)</strong>&lt;br&gt;Chair: Cindy Martin-Brennan, Executive Director, ASGSR</td>
</tr>
<tr>
<td>12:00–2:00 pm</td>
<td><strong>ASGSR Communication Committee Meeting (1:00-2:00 pm)</strong>&lt;br&gt;Chair: Dr. Kevin Sato, Lockheed Martin/ NASA Ames Research Center</td>
</tr>
<tr>
<td>12:00–2:00 pm</td>
<td><strong>Workshop V: Microscopes on the ISS (12:30-2:00 pm) (page 44)</strong>&lt;br&gt;Chair/Organizer: Fred Kohl, Ronald Sicker, William Meyer, Patricia Parsons-Wingerter (NASA Glenn Research Center)</td>
</tr>
<tr>
<td>2:00–3:30 pm</td>
<td><strong>Concurrent Session 39: Enabling Technology 2 (C39, pages 100-101)</strong>&lt;br&gt;Session Chair: Jose Nunez, NASA Kennedy Space Center</td>
</tr>
<tr>
<td>2:00-2:15 pm</td>
<td>[C39.1] A Microfluidic, High Throughput Protein Crystal Growth Method for Microgravity. Carl W. Carruthers, Jr., Houston Methodist Research Institute, Department of Genomic Medicine, Houston, Texas, USA.</td>
</tr>
<tr>
<td>2:30-2:45 pm</td>
<td>[C39.3] Instrumentation Development for Experiments in μ- and hyper-Gravity. Christian Schwarz, Life and Physical Sciences Instrumentation and Life Support Section, Mechanical Engineering Department, ESTEC-ESA, NL.</td>
</tr>
<tr>
<td>Time</td>
<td>Session/Presentation</td>
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<tr>
<td>2:45-3:00 pm</td>
<td>[C39.4] Plant Habitat: The Largest Plant Growth Hardware Destined for Implementation on ISS. Howard Levine, NASA Utilization and Life Science Directorate, Kennedy Space Center, FL, USA.</td>
</tr>
<tr>
<td>2:00–3:30 pm</td>
<td>Concurrent Session 40: Vertebrates 4 (C40, pages 101-103)</td>
</tr>
<tr>
<td></td>
<td>Session Chair: Joe Tash, University of Kansas Medical Center</td>
</tr>
<tr>
<td>2:00-2:15 pm</td>
<td>[C40.1] Overcoming Cardiovascular Challenges of Interplanetary Flight: May the Force of Pressure be with You. Alan R. Hargens, Department of Orthopaedic Surgery, University of California, San Diego, San Diego, CA, USA.</td>
</tr>
<tr>
<td>2:15-2:30 pm</td>
<td>[C40.2] Modeling of the Cephalad Cerebrospinal Fluid Shift Contribution to Elevated Intracranial Pressure in Microgravity. Rong-Wen Tain, Department of Radiology, Miller School of Medicine, University of Miami, Miami, FL, USA.</td>
</tr>
<tr>
<td>2:30-2:45 pm</td>
<td>[C40.3] Investigating the Relationship Between Ocular Blood Flow and Intracranial Pressure Towards a Noninvasive Measurement Methodology. Jeff A. Hawks, Dept. of Mechanical &amp; Materials Engineering, University of Nebraska, Lincoln, NE, USA.</td>
</tr>
<tr>
<td>2:45-3:00 pm</td>
<td>[C40.4] Human brain in microgravity: accuracy, precision, sensitivity and specificity of non-invasive intracranial pressure measurements. Rolandas Zakelis, Kaunas University of Technology, Telematics Science Laboratory, Kaunas, Lithuania.</td>
</tr>
<tr>
<td>2:00–3:30 pm</td>
<td>Concurrent Session 41: Fundamental Physics 5 – Atom Interferometry (C41, pages 103-104), Session Chair: Gary Burdick, NASA Jet Propulsion Laboratory</td>
</tr>
<tr>
<td>2:00-2:20 pm</td>
<td>[C41.1] Precision measurement and tests of the equivalence principle by atom interferometry in space. Holger Müller, Physics Dept, UC Berkeley, Berkeley, CA, USA.</td>
</tr>
<tr>
<td>2:20-2:40 pm</td>
<td>[C41.2] Prospects for Gravitational Wave Detection with Atom Interferometry. Jason M. Hogan, Department of Physics, Stanford University, Stanford, California, USA.</td>
</tr>
<tr>
<td>2:40-3:00 pm</td>
<td>[C41.3] Atom Interferometry and its Applications in Space. Jason Williams, Jet Propulsion Laboratory, California Institute of Technology, CA, USA.</td>
</tr>
<tr>
<td>3:00-3:20 pm</td>
<td>[C41.4] Circumvention of Inflation in the Closed Universe. Branislav Vlahovic, Department of Physics, North Carolina Central University, Durham, NC, USA.</td>
</tr>
<tr>
<td>2:00–3:30 pm</td>
<td>Concurrent Session 42: Combustion 3 – Microgravity Fire Safety and Flammability (Part 1) (C42, pages 104-105), Session Chair: Paul Ferkul, NASA Glenn Research Center</td>
</tr>
<tr>
<td>2:00-2:20 pm</td>
<td>[C42.1] Burning and Suppression of Solids – II Fire Safety Investigation for the Microgravity Science Glovebox. Sandra L. Olson, NASA Glenn Research Center.</td>
</tr>
<tr>
<td>2:20-2:40 pm</td>
<td>[C42.2] Overview of the Solid Combustion Experiment in the Japanese Experiment Module &quot;Kibo&quot; on the ISS. Masao Kikuchi, JAXA, Japan.</td>
</tr>
<tr>
<td>2:40-3:00 pm</td>
<td>[C42.3] Burning Characteristics of Paraffin and Japan Wax Candle Flames in a Low-Speed Oxidizing Stream in Microgravity. Fumiaki Takahashi, National Center for Space Exploration Research and NASA Glenn Research Center.</td>
</tr>
<tr>
<td>3:00-3:20 pm</td>
<td>[C42.4] A Novel Apparatus to Counter the Buoyancy Effect in Flame Spread Experiments. Subrata Bhattacharjee, Department of Mechanical Engineering, San Diego State University, San Diego, CA, USA.</td>
</tr>
<tr>
<td>3:20-3:40 pm</td>
<td>[C42.5] Large-Scale Spacecraft Fire Safety Experiments in ISS Resupply Vehicles. David Urban, NASA Glenn Research Center.</td>
</tr>
<tr>
<td>2:00–3:30 pm</td>
<td>Concurrent Session 43: Complex Fluids 1 (C43, page 106), Session Chair: Paul Ferkul, NASA Glenn Research Center</td>
</tr>
<tr>
<td>2:00-2:20 pm</td>
<td>[C43.1] Electrodeposition of Metals in Microgravity Conditions. Yasuhiro Fukunaka, JST-CREST, JAXA ISS Science Project Office, Nanotechnology Research Center, Waseda University.</td>
</tr>
<tr>
<td>Time</td>
<td>Session Details</td>
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<tr>
<td>3:30–4:00 pm</td>
<td>Afternoon Break Service</td>
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</tbody>
</table>
| 4:00–5:00 pm | Concurrent Session 44: Enabling Technology 3 (C44, pages 107-108)  
Session Chair: Kevin Sato, Lockheed Martin/ NASA Ames Research Center  
Salon V |
| 4:00-4:15 pm | [C44.1] Control of Ethylene in Spaceflight Plant Growth Chambers. Oscar Monje, Space Life Sciences Laboratory, ESC Team QNA, Kennedy Space Center, FL, USA. |
|             | [C44.2] Examining the CO₂ Dependent Relationships in a Membrane Aerated Biological Reactor Treating a Space-Based Wastewater. Dylan Christenson, Texas Tech University, Lubbock, TX, USA. |
| 4:30-4:45 pm | [C44.3] Development of a High-Intensity, Variable-Spectra LED Array for Optimized Plant Development in Challenging Environments. David Hawley, Controlled Environment Systems Research Facility, University of Guelph, Guelph, Ontario, Canada. |
| 4:45-5:00 pm | [C44.4] Off-Vertical Axis Rotational Assessment of Transdermal Scopolamine for Motion Sickness Prophylaxis. Glenn W. Knox, University of Florida Health – Jacksonville, Department of Surgery, Division of Otolaryngology. |
| 4:00–5:00 pm | Concurrent Session 45: Vertebrates 5 (C45, page 108)  
Session Chair: Amir Zeituni, Global Science & Technology, Inc., National Institute of Allergy and Infectious Diseases  
Salon VI |
| 4:00-4:15 pm | [C45.1] Carotid and Femoral Intima Media Thickness Change During Long Term Confinement (Mars 500). Philippe Arbeille, Medicine Physiologie Spatiale (UMPS-CERCOM), University Hospital Trousseau, Tours, France. |
|             | [C45.2] Lower Body Negative Pressure Counter Short-Duration Head-Down-Tilt Induced Elevation in Intraocular Pressure. Brandon R. Macias, Department of Orthopaedic Surgery, University of California-San Diego, San Diego, CA, USA. |
| 4:00–5:00 pm | Concurrent Session 46: Fundamental Physics 6 – Dusty Plasmas (Part 2) (C46, page 109), Session Chair: Uwe Konopka, Auburn University  
Salon VII |
| 4:00-4:20 pm | [C46.1] Distribution and Ordering of Fine Particles in Cylindrical Discharges under Gravity. Hiroo Totsuji, JAXA/ISAS, Tsukuba, Japan. |
| 4:20-4:40 pm | [C46.2] Development and application of particle image velocimetry for PlasmaLab. Edward Thomas, Jr., Physics Department, Auburn University, Auburn, AL, USA. |
| 4:40-5:00 pm | [C46.3] Transport Measurements in Dusty Plasmas under Microgravity Conditions. John Goree, Dept. of Physics and Astronomy, The University of Iowa, Iowa City, Iowa, USA. |
| 4:00–5:20 pm | Concurrent Session 47: Combustion 4 – Microgravity Fire Safety and Flammability (Part 2) (C47, pages 109-110)  
Session Chair: Sandra Olson, NASA Glenn Research Center  
Salon VIII |
| 4:00-4:20 pm | [C47.1] Thickness and Fuel Preheating Effects on Material Flammability in Microgravity from the BASS Experiment. Paul Ferkul, National Center for Space Exploration Research, NASA Glenn Research Center. |
| 4:20-4:40 pm | [C47.2] Flame Spread over a Thin PMMA Sheet in Low Oxygen Level under Microgravity Condition. Shuhei Takahashi, Department of Mechanical Engineering, Gifu University, Gifu, Japan. |
| 4:00–5:00 pm | Concurrent Session 48: Complex Fluids 2 (C48, pages 110-111)  
Session Chair: Ronald Sicker and Brian Motil, NASA Glenn Research Center  
Crystal |
| 4:00-4:20 pm | [C48.1] Coarsening of Wet Aqueous Foams in Microgravity. Douglas Durian, University of Pennsylvania, Department of Physics and Astronomy, Philadelphia, PA, USA. |
| 4:20-4:40 pm | [C48.2] Phase separation of colloid-polymer mixtures in microgravity: BCAT to ACE. Peter J. Lu, Department of Physics and SEAS, Harvard University, Cambridge MA, USA. |
### Detailed Daily Schedule

#### Thursday, November 7, 2013

<table>
<thead>
<tr>
<th>Time</th>
<th>Event</th>
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<tbody>
<tr>
<td>5:00–5:30 pm</td>
<td>Information Session VI: CIR/FIR Facilities (page 46)</td>
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<td></td>
<td>Chair/Organizer: Kirt Costello, NASA Johnson Space Center</td>
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<tr>
<td>6:00–7:00 pm</td>
<td><strong>ASGSR Mixer (cash bar)</strong></td>
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<td>7:00–10:00 pm</td>
<td>ASGSR Banquet and Awards Ceremony</td>
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<td></td>
<td>Keynote Speaker: Dr. Donald Pettit, NASA Astronaut <em>(presented by Techshot, Inc.)</em></td>
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#### Friday, November 8, 2013

<table>
<thead>
<tr>
<th>Time</th>
<th>Event</th>
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<tr>
<td>7:00 am–1:00 pm</td>
<td>Registration Open</td>
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<tr>
<td>7:00–8:30 am</td>
<td>Continental Breakfast</td>
</tr>
<tr>
<td>8:00 am–12:00 pm</td>
<td>Exhibits – All Day</td>
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<tr>
<td>8:00–10:00 am</td>
<td>Concurrent Session 49: Fluid Physics 10 (C49, pages 112-113)</td>
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<td>Session Chair: Walter M.B. Duval, NASA Glenn Research Center</td>
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<tr>
<td>8:00–10:00 am</td>
<td>Concurrent Session 50: Complex Fluids 3 (C50, pages 113-115)</td>
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<tr>
<td></td>
<td>Session Co-Chairs: Olivier Minster (ESA) and Paul Chaikin (New York University)</td>
</tr>
<tr>
<td>8:00–10:00 am</td>
<td>Concurrent Session 51: Combustion 5 – Droplet Combustion (Part 2)</td>
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<td></td>
<td>(C51, pgs 115-117), Session Co-Chairs: Dennis Stocker/ Vedha Nayagam, NASA GRC</td>
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</tbody>
</table>
### Detailed Daily Schedule

**Friday, November 8, 2013**

<table>
<thead>
<tr>
<th>Time</th>
<th>Session</th>
<th>Location</th>
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</thead>
<tbody>
<tr>
<td>8:40-9:00 am</td>
<td>[CS1.3] Cool flames in microgravity droplet combustion. Alberto Cuoci, Department of Chemistry, Materials, and Chemical Engineering, Politecnico di Milano (Italy).</td>
<td></td>
</tr>
<tr>
<td>9:20-9:40 am</td>
<td>[CS1.5] Multistage Oscillatory “Cool Flame” Behavior For Isolated Alkane Droplet Combustion in High Pressure Microgravity Condition. Tanvir Farouk, Department of Mechanical Engineering, University of South Carolina, Columbia, SC, USA.</td>
<td></td>
</tr>
<tr>
<td>9:40-10:00 am</td>
<td>[CS1.6] Droplet Combustion Dynamics of Butanol Isomers in a Reduced Gravity Environment. Y.C. Liu, Sibley School of Mechanical and Aerospace Engineering, Cornell University, Ithaca, NY, USA.</td>
<td></td>
</tr>
<tr>
<td>8:30–10:00 am</td>
<td><strong>Information Session VII: Space Life and Physical Science Hot Topics Status/Updates</strong> <em>(page 46)</em>, Chair/Organizer: David Tomko, NASA Headquarters</td>
<td>Salon I-IV</td>
</tr>
<tr>
<td>10:00–10:30 am</td>
<td><strong>Morning Break Service</strong></td>
<td>Grand Foyer</td>
</tr>
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</table>
| 10:30 am–12:00 pm | **Workshop VI: NASA Life Sciences Proposal Workshop** *(page 44)*  
Chair/Organizer: Howard Levine, NASA Kennedy Space Center | Salon I-IV     |
| 10:30 am–12:00 pm | **Workshop VII: Open Source Physical Science Workshop** *(page 44)*  
Chair/Organizer: Fran Chiaramonte (NASA Headquarters) and Fred Kohl (NASA Glenn Research Center) | Salon V         |
| 10:30 am–12:00 pm | **Concurrent Session 52: Complex Fluids 4 (CS2, page 117)**  
Session Co-Chairs: Fran Chiaramonte (NASA HQ) and Arjun Yodh (Univ. of Pennsylvania) | Salon VII       |
| 10:30-10:50 am | [CS2.1] Understanding the Link Between Bijel Morphology, Stability, and Processability. Ali Mohraz, Department of Chemical Engineering and Materials Science, University of California, Irvine. |               |
| 10:50-11:10 am | [CS2.2] Crystallization of Supercubes by Depletion. Andrew Hollingsworth, Dept. of Physics, New York University, New York, NY, USA. |               |
| 11:10-11:30 am | [CS2.3] Electric Field-Driven Phase Transitions in Polarized Colloids. Boris Khusid, New Jersey Institute of Technology, Newark, NJ, USA. |               |
| 11:30-11:50 am | [CS2.4] Colloidal Discotic Liquid Crystals. Zhengdong Cheng, Artie McFerrin Department of Chemical Engineering, TAMU, College Station, Texas, USA. |               |
| 12:00 pm | **Official close of ASGSR/ISPS Meeting; refer to General Schedule for post-meeting activities** |               |
Donald R. Pettit, Ph.D., was born in 1955 in Silverton, Oregon. He graduated from Silverton Union High School, Silverton, Oregon, in 1973; received a Bachelor of Science in Chemical Engineering from Oregon State University in 1978 and a Doctorate in Chemical Engineering from the University of Arizona in 1983.

Dr. Pettit served as staff scientist at Los Alamos National Laboratory, Los Alamos, New Mexico from 1984 to 1996. Projects included reduced gravity fluid flow and materials processing experiments onboard the NASA KC-135 airplane, atmospheric spectroscopy on noctilucent clouds seeded from sounding rockets, fumarole gas sampling from volcanoes and problems in detonation physics. He was a member of the Synthesis Group, slated with assembling the technology to return to the moon and explore Mars (1990) and the Space Station Freedom Redesign Team (1993).

Selected by NASA in April 1996, Dr. Pettit reported to the Johnson Space Center in August 1996. A veteran of three spaceflights, Dr. Pettit has logged more than 370 days in space and over 13 EVA (spacewalk) hours. He lived aboard the International Space Station for 5-1/2 months during Expedition 6, was a member of the STS-126 crew, and again lived aboard the station for 6-1/2 months as part of the Expedition 30/31 crew.

Dr. Pettit has spent a total of 370 days in space in three flights:

1. Expedition 6 (November 23, 2002 to May 3, 2003). Dr. Pettit completed his first spaceflight as NASA International Space Station Science Officer aboard the station, logging more than 161 days in space, including over 13 EVA hours.

2. STS-126 Endeavour (November 14 to November 30, 2008) was NASA’s 4th shuttle flight in 2008 and the 27th shuttle/station assembly mission. Highlights of the almost 16-day mission included expanding the living quarters of the International Space Station to eventually house six-member crews. During the mission, Dr. Pettit operated the robotic arm for a total of four EVAs performed by three members of the crew. STS-126 returned to Earth after completing 250 orbits in more than 6 million miles.

3. Expedition 30/31 (December 21, 2011 to July 1, 2012) launched to the International Space Station aboard the Soyuz TMA-03M craft from Kazakhstan. NASA Flight Engineer Don Pettit, Russian Soyuz Commander Oleg Kononenko and European Space Agency Flight Engineer Andre Kuipers of the Netherlands docked to the Rassvet module of the station on December 23, 2011 restoring the station’s crew complement to six. They continued scientific research and marked a new era of commercial resupply services from the United States by greeting the first SpaceX Dragon spaceship. Dr. Pettit landed in Kazakhstan after 193 days in space orbiting the Earth 3,088 times and traveling more than 76 million miles.

Biography and Photo courtesy of NASA
Dr. Joseph S. Tash, ASGSR President
University of Kansas Medical Center
Kansas City, Kansas, USA

Joseph S. Tash, PhD, is current President of the American Society for Gravitational and Space Research. He is a Professor in the Department of Molecular and Integrative Physiology, and the Department of Urology, at the University of Kansas Medical Center, Kansas City, KS, and former Director of the NIH U54 Interdisciplinary Center for Male Contraceptive Research and Drug Development. His experiences as PI on multiple NASA ground and flight projects, as well as director of a multi-university NIH-funded Cooperative U54 center have established his abilities to work in a collaborative environment involving multidisciplinary scientists, government agencies and contractors, as well as Program Directors. He has been a member of ASGSB since 1996, when he obtained his first NASA grant, and the AIAA (American Institute of Aeronautics and Astronautics) since 2007. His NASA-related research interests include the effects of space flight on male and female reproductive systems, reproductive health, and translational research on the development of spaceflight countermeasures. He was PI on two NASA flight experiments on STS-81, and STS-84, and was an investigator on the Biospecimen Sharing Program for STS-131, STS-133, STS-135, and is part of the BSP team for the BION M1 mission that just completed in 2013. He has also been NASA funded for ground based experiments at NASA ARC, using the 24ft centrifuge facility and collaborated with investigators at NASA, ESTEC (European Space Research and Technology Centre), and DLR (German Aerospace Center). Joe is PI on a newly funded NASA flight grant that will determine metabolomic and sperm function changes during activation of mouse and sea urchin sperm in microgravity. His flight and ground experiments have utilized a variety of animal and cell models, as well as animal and cell flight and ground hardware, and have incorporated broad disciplinary analytical techniques in animal physiology, organ function, cell-based, and molecular/gene regulation. Dr. Tash has served on previous NASA peer review committees. He is currently President-elect of ASGSR, and a member of the ASGSB Board of Governors (2009- present), has served on the ASGSB Congressional Round Robin Education subcommittee since 2006 that meets with congressional and senate staffers, and was a member of the ASGSB Board of Governors 2006-2007. Dr. Tash wrote a White Paper for the 2010 NASA Decadal Study by the Institute of Medicine, and was interviewed by ProOrbis to provide input on developing a management model for the newly established ISS National Laboratory. He recently has been instrumental in bridging the gap between fundamental, translational, and clinical research in the presentation of a Grand Rounds of his research to the NASA JSC flight surgeons in April 2011, and an Aerospace Medicine Grand Rounds to the USRA in Sept 2011. He also formally presented and discussed his NASA research in the context of planning for long term space exploration with the NASA Chief Scientist, Waleed Abdalati and other NASA HQ staff in Sept, 2011. Dr. Tash is also participating in the meetings/communications with NASA and CASIS as preparations are made for the transition to commercial space flight capabilities to enable rodent experiments on the ISS National Laboratory.

Dr. Fran Chiaramonte, ISPS Meeting Chair
NASA Headquarters
Washington, DC, USA

Fran Chiaramonte, Ph.D. is the Program Executive for NASA’s Physical Sciences Research Program at NASA HQ. He has have been the program executive for the past seven years and rebuilt the program from five experiments being developed for the ISS, to 25 today. He also promotes international science collaboration on the ISS resulting in 24 new experiments sponsored by other national space agencies with US investigators participating. In addition, twenty experiments on the ISS have been completed under his watch. He also expanded the program from two disciplines (fluids and combustion) to five disciplines adding complex fluids, materials science and fundamental physics. He led the effort, working with the Physical Science Center leads, to produce the 2012 Physical Science Research Plan. Prior responsibilities include Enterprise Scientist for
Fluid Physics at HQ for two years, manager of the Fluid Physics ground based experiments at GRC, and Project Scientist of four Space Shuttle experiments in fluids and materials science. One of those experiments, Pool Boiling, he guided the PI and worked with the engineering team from the proposal stage to the final flight (five total) gaining experience of the entire space flight development process. He has been involved in NASA’s Microgravity program for 25 years. He also served as the NASA representative to the DOD Space Experiments Review Board (SERB) from 2008-2011. He is on the organizing committee for the ASGSR 2012 Conference.

**DR. MARTIN U. ZELL**
Head of ISS Utilization and Astronaut Support Dept., Directorate of Human Spaceflight and Operations
European Space Agency

Dr. Martin Zell is responsible for the overall European Programme for Life & Physical Science in Space (ELIPS) comprising the coordination of life and physical sciences and human exploration preparation related research, the development of all related payloads and the operation of ESA’s mission platforms comprising Ground-based Facilities, Droptower, Parabolic Flights, Sounding Rockets (MASER, TEXUS, MAXUS), Orbital Capsules and focally the International Space Station with ESA’s Columbus module. In addition he is also responsible for all ESA Astronaut support activities concerning training and crew medical operations at the European Astronaut Centre. Martin Zell joined ESA in March 2003 and has been continuously responsible for the Utilization Department.

Zell worked since 1988 for almost 15 years in space industry (Dornier/DASA/Astrium) developing and operating namely SpaceLab payloads in the 90’s and then focusing on the development of the 1st generation of European ISS rack payloads for Columbus and P/L barters with NASA (incl. related experiments). Before he joined ESA he was the Head of the Astrium Payload Center in Friedrichshafen/Germany.

Zell was educated at the Technical University of Munich/D, acquiring a mechanical engineering diploma and gaining a PhD in engineering about heat and mass transfer phenomena in pool boiling under microgravity conditions which he experienced in many parabolic flights and Sounding Rocket experiments.

**DR. MASAHIRO TAKAYANAGI**
Senior Scientist and Director of the ISS Science Project Office, Institute of Space and Astronautical Science (ISAS) of the Japan Aerospace Exploration Agency (JAXA)

Dr. Takayanagi was born in Aichi pref. of Japan in 1958 and spent his days there until 18 years old, the graduation of high school and then entered the University of Tokyo. He has majored in the earth and planetary science in the faculty of science of the University of Tokyo and the graduate school of the University of Tokyo. His doctoral degree is on the trace elements in extraterrestrial materials such as noble gases in cosmic dusts. After ten years’ experience of development of space experiment facilities and earth observation sensors in a space-related company, he moved to the National Space Development Agency of Japan (NASDA), the former JAXA. In October 2003, JAXA has established after the merger of three Japanese governmental space and aeronautical agencies including NASDA. At the moment of establishment of JAXA, the ISS Science Project Office has also organized in ISAS to promote and coordinate scientific use of ISS and science fields utilizing the space environment by other kinds of space experiment opportunities. His carriers throughout from his university days to today have been related space science and utilization and he has played a role in the center of these histories shown above, especially in these twenty years in NASA and JAXA.

**DR. GU YIDONG**
President, Chinese Society of Space Research; Senior Consultant in Technology and Engineering Center for Space Utilization, Chinese Academy of Sciences

Prof. Yidong Gu has been engaged in the space utilization of China’s manned space program as it started in 1992. He was the Chief Commander & Chief Designer for space utilization system in the China’s manned space program. He now is Member of Chinese Academy of Sciences, and the President Of Chinese Society of Space Research, and the Leader of science planning group for China’s space station, and also senior consultant in Technology and Engineering Center for Space Utilization, Chinese Academy of Sciences.

**DR. ELLEN STOFAN**
NASA Chief Scientist

Dr. Ellen Stofan was appointed NASA chief scientist on August 25, 2013, serving as principal advisor to NASA Administrator Charles Bolden on the agency’s science programs and science-related strategic planning and investments.

Prior to her appointment, Stofan was vice president of Proxemy Research in Laytonsville, Md., and honorary professor in the department of Earth sciences at University College London in England. Her research has focused on the geology of Venus, Mars, Saturn’s moon Titan, and Earth. Stofan is an associate member of the Cassini Mission to Saturn Radar Team and a co-investigator on the Mars Express Mission’s MARSIS sounder. She also was principal investigator on the Titan Mare Explorer, a proposed mission to send a floating lander to a sea on Titan.

Her appointment as chief scientist marks a return to NASA for Dr. Stofan. From 1991 through 2000, she held a number of senior scientist positions at NASA’s Jet Propulsion Laboratory in Pasadena, Calif., including chief scientist for NASA’s New Milleni-
um Program, deputy project scientist for the Magellan Mission to Venus, and experiment scientist for SIR-C, an instrument that provided radar images of Earth on two shuttle flights in 1994.

Stofan holds master and doctorate degrees in geological sciences from Brown University in Providence, R.I., and a bachelor’s degree from the College of William and Mary in Williamsburg, Va. She has received many awards and honors, including the Presidential Early Career Award for Scientists and Engineers. Stofan has authored and published numerous professional papers, books and book chapters, and has chaired committees including the National Research Council Inner Planets Panel for the recent Planetary Science Decadal Survey and the Venus Exploration Analysis Group.

**DR. D. MARSHALL PORTERFIELD**

Division Chief, NASA Space Life and Physical Sciences Research and Applications Division, NASA Headquarters
Washington, DC, USA

D. Marshall Porterfield, Ph.D., is Division Director of NASA’s Space Life and Physical Sciences Research and Applications Division where he oversees and manages Fundamental Space Biology, Physical Sciences, and all Human Research within NASA while providing oversight to the International Space Station National Lab. He is a lead interagency contact between NASA and the National Institutes of Health, National Science Foundation, and the U.S. Department of Agriculture.

Dr. Porterfield is an Associate Professor at Purdue University, where he holds academic appointments in the departments of Agricultural & Biological Engineering, Horticulture & Landscape Architecture, and Biomedical Engineering. In 2009 he was awarded the University Faculty Scholar award, Purdue’s highest mid-career faculty award. He is the director of the Bindley Bioscience Center-Physiological Sensing Facility, where work is focused on the development and application of biosensors and MEMS microdevices for agricultural, environmental, biomedical, and space biology research applications. His research interests include biophysically mediated plant stress responses during spaceflight, and cellular signaling for gravisensing in single cells. He has worked on CHROMEX-03, -04, and -05, Astroculture 04, and the CUE spaceflight experiments, and recently flew the Microfluidic Ion Sensor Array experiment on the C-9. He has served as editor for Advances in Space Research and on the editorial board for the journal Sensors. He is currently a member of the ASGSB Governing Board (2006–09) and the Finance Committee (since 2004) and recently assumed the role of Chair of the Communications Committee. He first joined ASGSB as a doctoral student in 1993 and was honored with the ASGSB Halstead Young Investigator Award in 2006.

**DR. JULIE A. ROBINSON**

Chief Scientist, ISS Program
NASA Johnson Space Center
Houston, Texas, USA

Dr. Julie A. Robinson is the Chief Scientist for the International Space Station (ISS) for the National Aeronautics and Space Administration (NASA) at Johnson Space Center. She represents all ISS research disciplines and provides information and recommendations at the highest levels at NASA and to stakeholders outside of NASA. She chairs the ISS Program Science Forum, made up of the senior scientists for each of the space agencies in the ISS international partnership. As ISS Program Scientist, Robinson has overseen the transition of the laboratory from the assembly period, with just a few dozen active investigations, to full utilization, with hundreds of active investigations.

Dr. Robinson has an interdisciplinary background in the physical and biological sciences. Her professional experience has included research activities in a variety of fields, including virology, analytical chemistry, genetics, statistics, field biology, and remote sensing. She has authored over 50 scientific publications.

**INVITED SPEAKERS:**

**MS. ANN M. ZULKOSKY,** Senior Professional Staff, Senate Commerce, Science and Transportation Committee

**REPRESENTATIVE,** NASA Space Technology Mission Directorate,
Game Changing Technology
SYMPOSIUM I

SPACE RADIATION:
RISKS, RESEARCH AND
COUNTERMEASURES

Tuesday, November 5, 2013
8:30 am—12:00 pm

CHAIR: DR. WILLIAM ATWELL
The Boeing Company
Houston, Texas, USA

William Atwell is a technical fellow with the Boeing Company and currently supports the AeroThermal Group. Mr. Atwell has 40 years of experience in the areas of the space radiation environment, high-energy particle transport through materials, active and passive dosimetry, spacecraft, satellite, and anatomical modeling/shielding analysis, radiation detection instrumentation, biological and physical effects, and data analyses. He is one of the original members of the NASA Johnson Space Center (JSC) Space Radiation Analysis Group. Recently, his interests and support activities have been in space radiation research projects for NASA, the European Space Agency, and the German Space Agency. He has been on the science teams for the 2001 Mars Odyssey Martian Radiation Environment Experiment and the Boeing Jupiter Icy Moons Orbiter Phase A study. He provides support to the NGC/Boeing Crew Exploration Vehicle proposal effort and the JSC-requested Radiation Trade studies. Mr. Atwell was a chair of the AIAA Life Science and Systems Technical Committee and is chair of the AIAA Life Sciences and Space Processing Technical Committee and a member of the AIAA Public Policy Technical Committee. Mr. Atwell is the recipient of the Astronaut’s Silver Snoopy Award, Rockwell International Space Systems Division (now Boeing) President’s Award, and numerous NASA, NATO, and AIAA awards and commendations. He received the 2001 Special Space Flight Achievement Award from JSC for his scientific support, modeling efforts, and space radiation analyses of the Phantom Torso Experiment (1998) and the International Space Station Increment 2 (2001). Mr. Atwell has authored more than 200 technical and scientific publications. He has an M.S. in physics/mathematics from Indiana State University and was a Ph.D. candidate at the University of Florida.

DR. FRANCIS CUCINOTTA
University of Nevada, Las Vegas
Las Vegas, Nevada, USA

Dr. Francis A. Cucinotta is a Professor of Health Physics at the University of Nevada, Las Vegas. Dr. Cucinotta received his Ph.D. in nuclear physics from Old Dominion University. He was a NASA Graduate Student Research Fellow from 1985-1988. He worked for the Department of Energy’s at the Environmental Measurements Lab in New York from 1988 to 1989. He was a Senior Research Scientist at NASA Langley Research Center from 1991 to 1997. In 1995-1996 he was awarded the Floyd L. Thompson Research Fellowship and studied molecular biology at the Johns Hopkins University Oncology Center and the Medical Research Council of the United Kingdom Genome Stability Unit in Harwell. From 1997 to 2013, Dr. Cucinotta worked at the NASA Johnson Space Center as the Radiological Health Officer, NASA Space Radiation Project Manager and Chief Scientist. Dr. Cucinotta developed the astronaut exposure data base of organ doses and cancer risk estimates for all missions from Mercury to ISS, and developed risk models for acute, cancer and circulatory disease risks. He managed the construction of the NASA Space Radiation Lab (NSRL) from 1998 to 2003, and NSRL Operations from 2003 to 2012. Dr. Cucinotta worked on radiation safety in NASA’s mission control for the Space Shuttle and ISS programs in 1989 and 1990, including during the October of 1989 Solar event, and in 2000-2006 during numerous other solar events. Dr. Cucinotta has published over 300 research publications, numerous book chapters and over 200 NASA Technical Reports. He has published extensively in nuclear physics, space radiation physics, radiation shielding, DNA damage and repair models, biodosimetry, systems biology, and risk assessments for acute and late radiation effects. Dr. Cucinotta led the development of the NASA Space Cancer Risk model (NSCR-2012) and the Relativistic Ion Tracks (RITRACKS) computer codes, winners of NASA JSC Software of the Year in 2013 and 2012, respectively. He has won numerous other NASA Awards for his efforts in research, mission safety, and research management. Dr. Cucinotta is currently the President of the International Radiation Research Society, and an elected Council Member of the National Council of Radiation Protection and Measurements (NCRP). He has co-authored NCRP and International Commission on Radiological Protection (ICRP) reports on space radiation risks to humans.
**DR. CARY ZEITLIN**  
Southwest Research Institute  
Boulder, Colorado, USA

Dr. Zeitlin received his bachelor’s degree in physics from the University of California, Berkeley, in 1981. He received his Ph.D. in experimental particle physics from U.C. Davis in 1988, having worked on the TPC/Two-Gamma experiment at the Stanford Linear Accelerator Center. His postdoctoral work was also at SLAC, on the SLAC Large Detector experiment which made precision measurements of the Z0 boson. In 1991, at the conclusion of his postdoctoral work, Dr. Zeitlin became a Staff Scientist at the Lawrence Berkeley National Laboratory, where he worked in the field of experimental nuclear physics, measuring nuclear interaction cross sections that are important to NASA for the development of space radiation transport models. Experiments were conducted at the Heavy Ion Medical Accelerator facility in Chiba, Japan, and at NASA beam lines at the Brookhaven National Laboratory. During his time at LBNL, the Martian Radiation Environment Experiment (MARIE) was launched to Mars aboard the 2001 Mars Odyssey spacecraft. Though not initially a part of the MARIE team, Dr. Zeitlin was invited to lead the team following the sudden, unexpected passing of the Principal Investigator, Dr. Gautam Badhwar of NASA Johnson Space Center. This marked the beginning of a career transition away from ground-based experiments to spaceflight experiments. In 2008, Dr. Zeitlin moved from LBNL to Southwest Research Institute to work on the Radiation Assessment Detector (RAD) for the Curiosity rover, which at that time was being assembled and tested prior to delivery to NASA. Also in 2008, Dr. Zeitlin joined the science team for the Cosmic Ray Telescope for the Effects of Radiation (CRaTER) instrument, which was launched into lunar orbit in 2009. In 2011, after a two-year delay, Curiosity was launched to Mars with RAD aboard and operating for most of the outbound journey. This allowed the RAD team to make a unique measurement: monitoring the deep space radiation environment inside a heavily shielded spacecraft on its way to Mars. Following the successful landing of Curiosity in August 2012, RAD has continued operating and the team has made the first detailed measurements of the radiation environment on the surface of another planet. Simultaneously, the CRaTER instrument has continued to operate and has sent back a very large volume of particle data, enabling detailed comparisons between lunar and Martian radiation environments. With the success of the RAD unit on Mars, NASA has procured a modified version (ISS-RAD) for operational use on the International Space Station. Dr. Zeitlin has been deeply involved in the design and testing of this new instrument, scheduled to be launched to ISS in 2014, with an expected operational life of at least 10 years.

**DR. GREGORY NELSON**  
Loma Linda University Medical Center  
Loma Linda, California, USA

Gregory Nelson earned his B.S. in chemistry from Caltech and his Ph.D. in Cell and Developmental Biology at Harvard Medical School in 1979 where his thesis work was on the genetics of sex determination and spermatogenesis in the nematode C. elegans. During a postdoctoral fellowship at Harvard he investigated regulation of cell surface distribution of immunoglobulin on lymphocytes and its control by the calcium regulator, calmodulin. He joined the Jet Propulsion Laboratory in 1982 where he became interested in the space radiation environment and developed C. elegans as a biodosimetry system for spaceflight applications. As principal investigator, he flew the nematode experiments using the European Space Agency’s Biorack facility on shuttle missions STS-42 (1992) and STS-76 (1996). He has since participated in shuttle missions STS-108, -118 and -135 examining effects of space-flight on the immune and nervous systems of mice as part of the commercial biotechnology technology mission experiments 1-3. The spaceflight experiences led him to participate in a number of NASA programmatic activities, including the design of a dedicated biological satellite (LifeSat) system. He joined Loma Linda University in 1996 to direct its new radiobiology program and to develop the infrastructure needed to do space research with proton beams. As the LLU radiobiology program grew, he was able to maintain a modest research activity with C. elegans, and later began collaborations on projects that have investigated the effects of protons and charged particles on immune responses, thyroid cells in 3-D tissue models, microvasculature, and rodent behavior. More recently he served as principal investigator on two NASA program projects (NSCOR) team involving nine institutions that investigate how space-like radiation exposures produce time- and dose-dependent changes in the mouse brain. He was a founding director of NASA’s Space Radiation Summer School held at the Brookhaven National Laboratory and serves as a member of the National Council on Radiation Protection and Measurements. He recently completed a NASA-funded study investigating genes regulating bystander effects in C. elegans in a study involving RNA interference screening and microbeam-based experiments in collaboration with Professors Leslie Braby and John Ford of Texas A&M University and was appointed Adjunct Professor of Nuclear Engineering at TAMU in 2008. Another ongoing study funded by DOE investigates the effects of low doses of gamma rays on adaptive immunity in the mouse. Dr. Nelson is currently Professor of Basic Sciences and Radiation Medicine at Loma Linda University.
**DR. MARY HELEN BARCELLOS-HOFF**  
New York University Medical Center  
New York, New York, USA

Dr. Barcellos-Hoff joined New York University School of Medicine in 2008 as an Associate Professor and Director of Radiation Biology in the Department of Radiation Oncology. She received tenure as Professor in 2010. She is Principal Investigator of a competitive 5-year, multi-institutional program project for NASA on space radiation health effects awarded in 2009. She currently is Principal or Co-Investigator of seven currently funded research projects from NIH, DOD, DOE, NASA and industry. Dr. Barcellos-Hoff has published more than 65 primary research publications, most recently in Cancer Cell, as well as more than 70 book chapters, invited reviews and editorials. Her research has led the field in defining the complexity of radiation effects on biological systems and the mechanisms underlying radiation carcinogenesis. She instigated systems biology approaches to radiation biology in 2005, leading four international workshops. She holds a patent for modulation of TGFβ in radiotherapy, which is the subject of research developed at NYU in collaboration with clinical faculty and is now the basis for a clinical trial in metastatic breast cancer. She is founding science editor of Integrative Biology, a new journal dedicated to publishing innovative technology driving biological insight, as well as member of several editorial boards. Dr. Barcellos-Hoff received her undergraduate degree from the University of Chicago and earned a doctoral degree in experimental pathology from the University of California, San Francisco on the response to chemotherapy and radiation in brain tumors. She conducted postdoctoral research on the extracellular matrix and functional differentiation at the Lawrence Berkeley National Laboratory, where she spent 20 years studying breast cancer and radiation. She rose from postdoctoral fellow to Senior Scientist and Associate Director of the Life Sciences Division, where she led multi-investigator programs in radiation biology and health effects. Dr. Barcellos-Hoff actively participates in science communication, including a widely disseminated video, “Of Mice and Women”, produced by Michael Hoff Productions. Her laboratory works on parallel projects on systems biology of radiation carcinogenesis and biologically augmented radiotherapy.

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**DR. JERRY SHAY**  
University of Texas Southwestern Medical Center  
Dallas, Texas, USA

Jerry W. Shay is the Vice Chairman of the Department of Cell Biology at The University of Texas Southwestern Medical Center in Dallas, an Associate Director of the Harold Simmon’s Comprehensive Cancer Center, and holds the Southland Corporation Distinguished Chair in Geriatrics Research. Throughout his career, Dr. Shay has been interested in the relationships between aging and cancer. His seminal work on the relationships of telomerase to aging and cancer has received much international recognition. He received the AlliedSignal Award for Research on Aging, the Ted Nash Foundation Award, and the American Association of Aging Hayflick Award together with his long term collaborator, Dr. Woodring E. Wright. Dr. Shay was also named an Ellison Medical Foundation Senior Scholar in Aging Research. Dr. Shay was placed in the Institute for Scientific Investigations as one of the most highly cited scientists in the field of “Molecular Biology and Genetics”. Science Watch placed Dr. Shay into the Doctors of the Decade list and he was ranked as one the most cited authors in the area of General Biomedicine (Science Watch 17:1 2-3, 2006). The citation of his work by other scientists attests to the impact of Dr. Shay’s research (h index = 100). In addition to 21 issued patents, Dr. Shay has published over 400 peer reviewed scientific articles, written 80 book chapters and edited 10 books. He has recently applied his knowledge in human aging and cancer research to the question of increased risks of developing fatal cancer upon exposure to both low and high LET irradiation. He has also developed orally available anti-inflammatory, anti-oxidant modulatory compounds that prevent a significant proportion of the downstream detrimental effects of irradiation.

Dr. Shay is on the editorial board of several scientific journals and is also a member of biotechnology scientific advisory boards that focus on research in cancer and aging. Finally, Dr. Shay serves as the Chairman of the Scientific Review Committee for the Mary Kay Ash, Charitable Foundation, Chairman Scientific Advisory Board for the Center of Excellence in Genomic Medicine, Saudi Arabia, Hong Kong Research Grants Council, and is the Program Director of the Cancer Biology Graduate Program at UT Southwestern. Dr Shay holds the title of Distinguished Teaching Professor, is a member of the Southwestern Academy of Teachers, a member of the University of Texas Health Science Educators Academy, in 2012 was awarded a University of Texas Regent’s Outstanding Teaching Award, and in 2013 the Minnie Stevens Piper Foundation Professor award.
Dr. Anna-Lisa Paul
University of Florida
Gainesville, Florida, USA

Dr. Anna-Lisa Paul is an Associate Professor and Graduate Faculty in the Horticultural Sciences department at the University of Florida. She is also the current Graduate Coordinator for the Program in Plant Molecular and Cellular Biology. Paul is a plant molecular biologist with an interest in how plants respond to abiotic stress, particularly at the gene expression level. Venues associated with spaceflight provide an opportunity to explore plant genomic responses to a novel environment; one that is outside the evolutionary experience of terrestrial organisms. This unique platform presents a background by which adaptive strategies at the gene expression level can be observed as they are engaged to cope with a stress de novo. Paul and her colleague Robert Ferl have launched and analyzed five spaceflight experiments: a sortie on Shuttle Columbia (STS-93) in 1999, three telemetric and gene expression experiments on STS-129, -130 and -131, and also a BRIC-16 gene expression experiment on STS-131, and a BRIC-17 experiment on SpaceX-2. Paul and Ferl are currently preparing for upcoming flight experiments scheduled for SpaceX-3 and SpaceX-4. They have also been awarded suborbital flights through NASA’s Flight Opportunities Program. Paul and Ferl have conducted (and flown with) a variety of experiments on NASA’s parabolic flight aircraft to test biology and hardware for both microgravity and suborbital vehicle applications, as well as flown with their experiments on F-104 aircraft to test high-g operations. The research associated with these experiments relates to evaluating the effects of the spaceflight environment on the patterns of gene expression and signal transduction in the model plant Arabidopsis thaliana. These data have provided new insights into the mechanisms by which eukaryotic organisms sense and respond to their environment at the molecular level. Paul has served the space-biology community as a member of the International Space Station Standing Review Board (ISS-SRB) and the Suborbital Applications Researchers Group (SARG). She is also editor-in-chief of the journal Gravitational and Space Research.

Dr. Robert Ferl
University of Florida
Gainesville, Florida, USA

Dr. Rob Ferl is the Director of the Interdisciplinary Center for Biotechnology Research at the University of Florida, and a Professor in the department of Horticultural Sciences, and Program in Plant Molecular and Cellular Biology. He has launched several spaceflight experiments and conducted numerous experiments in spaceflight and planetary analog environments studying the effects of spaceflight and potential planetary habitats on plant molecular biology. He and his colleague Anna-Lisa Paul had two experiments on Space Shuttle missions STS-93 and STS-131, and four experiments launched and recovered from the International Space Station on STS-129, 130, and 131 and SpaceX-2. They are currently in the preparation stages for experiments on SpaceX-3 and 4. He has also flown with his experiments on several of NASA’s parabolic flight aircraft to mimic aspects of the microgravity environment and develop flight hardware (and Rob has himself accumulated nearly 2,000 parabolas) and has been awarded suborbital flights through the NASA Flight Opportunities Program. Ferl has also conducted high-g testing of the hardware and biology targeted for suborbital applications on F-104 Starfighters aircraft. He has been funded for ground based science on space-related environmental effects on plants, and for research on plant biology in planetary exploration analogs including the Haughton Mars Project located on the edge of Haughton Crater in the Canadian high arctic and in the low pressure chambers at the University of Guelph that allow approaches to surface conditions on Mars. Ferl was a member of the Plant and Microbial committee of the recent NAS Decadal Study and currently serves as Chair of the Science Council for the USRA Division of Space Life Sciences at JSC. He has published extensively on the subject of spaceflight and extraterrestrial plant growth and on the fundamentals of moving life off the surface of the earth.

Dr. Alan Stern
Southwest Research Institute
Boulder, Colorado, USA

Dr. Alan Stern is a planetary scientist, space program executive, aerospace consultant, and author. In 2007, he was named to the Time 100 and was appointed NASA’s chief of all science
missions. Since 2009, he has been an Associate Vice President at the Southwest Research Institute, and has since 2008 had his own aerospace consulting practice. Additionally, in 2011 he was appointed to be the Director of the Florida Space Institute. Dr. Stern is also the CEO of two small businesses and serves on the board of directors of the Challenger Center for Space Science Education and the Commercial Spaceflight Federation. He is currently training to fly a series of suborbital space research missions with Virgin Galactic and XCOR Aerospace in 2012-2013. Dr. Stern also serves as the Chief Scientist and Mission Architect for the Moon Express Google Lunar X-Prize Team. In 2007 and 2008, Dr. Stern served as NASA’s chief of all space and Earth science programs. Dr. Stern is the Principal Investigator (PI) of NASA’s $720M New Horizons’ Pluto-KuiperBelt mission, the largest Piled space mission ever launched by NASA. His career has taken him to numerous astronomical observatories, to the South Pole, and to the upper atmosphere aboard various high performance NASA aircraft including F/A-18 Hornets, F-104 Starfighters, KC-135 Zero-G, and WB-57 Canberras. He has been involved as a researcher in 24 suborbital, orbital, and planetary space missions, including 9 for which he was the mission principle investigator; and he has led the development of 8 scientific instruments for NASA space missions. In 1995, he was selected as a Space Shuttle mission specialist finalist, and in 1996 he was a candidate Space Shuttle Payload specialist. In 2010, he became a suborbital payload specialist trainee, and is expected to fly several space missions in 2012-2013. Dr. Stern’s academic research has focused on studies of our solar system’s Kuiper belt and Oort cloud, comets, the satellites of the outer planets, the Pluto system, and the search for evidence of solar systems around other stars. He has also worked on spacecraft rendezvous theory, terrestrial polar mesospheric clouds, galactic astrophysics, and studies of tenuous satellite atmospheres, including the atmosphere of the moon.

**DR. STEVE COLLICOTT**

Purdue University
West Lafayette, Indiana, USA

Steven Collicott is a Professor in the School of Aeronautics and Astronautics in the College of Engineering at Purdue University. Since beginning at Purdue in 1991 he has taught and researched a variety of two-phase fluids topics ranging from unsteady cavitation inside 200-micron diameter diesel fuel injector passages to propellant gauging in operational communications satellites. He has led the thirty-one parabolic aircraft flight experiments, is developing payloads for most sub-orbital rocket companies and a balloon company, aided in the design of the successful Vane Gap experiments in ISS and is presently the PI on the Fluids Education Experiment which is destined for the ISS.

Professor Collicott serves as Chair of the Sub-orbital Applications Researchers Group of the Commercial Spaceflight Federation, serves on the Science and Technology Advisory Board of CASIS, and is a long-time member of the AIAA’s Microgravity and Space Processing technical committee.

**DR. ERIKA WAGNER**

Blue Origin
Kent, Washington, USA

Dr. Erika Wagner serves as Business Development Manager for Blue Origin, a private firm developing vehicles to enable tourists and researchers to access space at dramatically lower cost and increased reliability. Prior to joining Blue Origin, Dr. Wagner worked with the X PRIZE Foundation as Senior Director of Exploration Prize Development and founding Executive Director of the X PRIZE Lab@MIT. Previously, she served at MIT as Science Director and Executive Director of the Mars Gravity Biosatellite Program, a multi-university spacecraft development initiative to investigate the physiological effects of reduced gravity. Her interdisciplinary academic background includes a bachelor’s in Biomedical Engineering from Vanderbilt University, a master’s in Aeronautics & Astronautics from MIT, and a PhD in Bioastronautics from the Harvard/MIT Division of Health Sciences and Technology. Her research spanned both human and mammalian adaptation to microgravity, partial gravity, and centrifugation; as well as organizational innovation and prize theory. She is also an alumna of the International Space University.

**MR. KYLE STEPHENS**

Virgin Galactic
Mohave, California, USA

Kyle Stephens serves as Payload Integration Engineer for Virgin Galactic, the world’s first commercial spaceline. In this role, Kyle is responsible for developing SpaceShipTwo’s suborbital research payloads program in addition to working directly with Principle Investigators interested in available opportunities. Kyle is also serving as Virgin Galactic’s Community Champion, allowing him to develop outreach initiatives that align with the goals established by Virgin Unite, the charitable arm of the Virgin Group. Prior to Virgin Galactic, Kyle worked for Ball Aerospace & Technologies Corp. in Boulder, CO and NASA’s Marshall Space Flight Center as a Research Associate in the NASA Academy Program. He has served on two crews at the Mars Desert Research Station, serving as Mission Commander for his most recent rotation. As a student, Kyle participated in NASA’s Reduced Gravity Student Flight Opportunities Program where he led a team in the development and testing of an optical technology payload. He graduated from the University of Arizona with a bachelor’s in Optical Sciences and Engineering.
Uncertainties in estimating health risks from exposures to galactic cosmic rays (GCR) — made up of high-energy protons and high-energy and charge (HZE) nuclei are an important limitation to long duration space travel. Experimental studies have shown that HZE nuclei produce both qualitative and quantitative differences in biological effects compared to terrestrial radiation leading to large uncertainties in predicting risks to humans. Our recent NASA Space Cancer Risk Model-2012 for estimating lifetime cancer risks from space radiation included several new features compared to the earlier NCRP models used at NASA, and are based in part on responses to recommendations by the U.S. National Academy of Sciences. Important features of the model were:

2. An analysis of lung cancer and other smoking-attributable cancer risks for never-smokers that shows significantly reduced lung cancer risks as well as overall cancer risks compared to risk estimated for the average U.S. population.
3. A new approach to define space radiation quality factor (QF) functions based on track-structure concepts, which depend on charge number, Z, and kinetic energy, E, and with probability distribution functions (PDF) to estimate QF uncertainties.
4. The assignment of a smaller maximum in the quality function for leukemia than for solid cancers risk estimates.
5. Revised uncertainty estimates for model coefficients (organ exposures, low-LET risk coefficients, DDREF, and QFs) to estimate overall cancer risk estimate uncertainties.

In this report we discuss new features for the 2014 Space Risk Projection (SRP) model, which include:

1. Updates to PDF’s for the space radiation QF functional parameters.
2. Consideration of correlations between QF and DDREF values based on limited experimental data for tumor induction and surrogate endpoints.

Example calculations for International Space Station missions and deep space missions to near-Earth objects and Mars are described.


frequently show a threshold and lack clear dose dependence. I will review recent experimental studies from the perspective that both targeted and non-targeted effects contribute to radiation carcinogenesis and discuss their relevance to understanding the cancer risk presented by the space radiation environment.

Supported by a NASA Specialized Center of Research (NSCOR).

[S1.4] Biological Countermeasures of Space Radiation-induced Invasive Carcinomas in Mouse Models of Lung and Colon Cancer. A. Kaisani\(^1\), S. B. Kim\(^1\), O. Delgado\(^1\), G. Fasciani\(^1\), K. Batten\(^1\), J.A. Richardson\(^2\), W. E. Wright\(^3\), M. D. Story\(^2\), J. D. Minna\(^2\), and J. W. Shay\(^1\). \(^1\)Department of Cell Biology, \(^2\)Pathology, \(^3\)Radiation Oncology, \(^4\)Internal Medicine and Hamon Center, UT Southwestern Medical Center, Dallas, TX.

Using lung and colon cancer susceptible mouse models we examined the effects of space radiation on cancer progression. The murine LA-1 model expresses mutated KRAS in a subset of lung cells resulting in initiation and formation of lesions that mimic lung cancer progression in humans. About 9% of LA-1 mouse spontaneously develop invasive non-small cell lung adenocarcinomas. We have compared this lung cancer mouse model with another mouse model of susceptibility to colorectal cancer. About 6% of CDX2P-NLS Cre; APC\(^{+/lop}\) (CPC;Apc) mice spontaneously develop invasive cancers. Very limited data are available on progression of cancer susceptible mice to advanced, perhaps fatal, invasive cancers after space irradiation (IR).

Studies included whole body proton IR as a single 2.0 Gy dose (50 MeV and 150 MeV) and as a simulated solar particle event (SPE), of 2.0 Gy over 2 hours with a wide range of energies (50 MeV-150 MeV). Histopathological analysis of irradiated LA-1 mice 70-100 days post-IR revealed an increase in both the number and size of lung hyperplastic lesions and adenomas. In addition, histopathological analysis of the LA-1 and CPC;Apc mice one year post-IR demonstrated a progression in tumor grade to invasive adenocarcinomas (lung 9-30% and colon 15-26%).

CDDO-EA (a synthetic triterpenoid ethyl amide) is an oral available anti-inflammatory/anti-oxidant modulator that has been tested in humans in a variety of clinical trials. We tested if the LA-1 and CPC;Apc mice fed CDDO-EA diet prior to proton or \(^{56}\text{Fe}\)-IR would have a lower incidence of invasive carcinoma. In the LA-1 mice fed CDDO-EA prior to 2.0 Gy SPE, the incidence of invasive cancers was reduced from 30% to 17%. In the CPC;Apc mice fed CDDO-EA prior to 2.0 Gy SPE, the incidence of invasive cancers was reduced from 26% to 11.6%. These mice were only fed CDDO-EA prior to IR and one day post-IR. These results indicate that exposure to solar particle IR and \(^{56}\text{Fe}\)-IR (data to be presented) increases the risk of invasive cancers in cancer susceptible mouse models, and that radioprotectors such as CDDO-EA may reduce the overall risk of fatal cancers. Supported by NASA Grants # NNX11AC15G, NNI05HD36G and NNX09AU95G.

[S1.5] Physical and Biological Measurement of Crew Doses and Results from Mars. C. Zeitlin\(^1\), D. M. Hassler\(^1\), R. F. Wimmer-Schweingruber\(^2\), B. Ehresmann\(^2\), S. C. Rafkin\(^1\), F. A. Cucinotta\(^1\), E. Boehm\(^2\), S. Boettcher\(^2\), S. Burmeister\(^2\), J. Guo\(^2\), J. Koehler\(^2\), A. Posner\(^3\), \(^1\)Southwest Research Institute, Boulder, CO, USA;
\(^2\)Christian Albrechts University, Kiel, Germany; \(^3\)University of Nevada Las Vegas, Las Vegas, NV, USA; \(^4\)NASA Headquarters, Washington, DC, USA.

The Radiation Assessment Detector (RAD) was launched to Mars aboard the Curiosity rover in November 2011. For most of the 253-day transit to Mars, RAD was turned on and made the first-ever radiation environment measurements inside a spacecraft bound for Mars, simulating the conditions that might be experienced by future human explorers. Following the successful landing of Curiosity on the surface, in August 2012, RAD began measurement of the radiation environment on the surface of Mars. RAD consists of a silicon detector telescope, a cesium iodide calorimeter for identification of medium-energy particles (protons with up to 100 MeV of kinetic energy, iron ions up to 500 MeV/nuc, etc.), and a neutron detector based on plastic scintillators. The charged particle detection system has a wide dynamic range, enabling RAD to measure almost all of the charged particles relevant to radiation exposure in space. Neutrons are detected with reasonable efficiency in the range from 10 MeV to a few hundred MeV. A complex inversion technique is employed to separate out the neutron and gamma-ray spectra; a brief overview of the method will be given. Data from RAD's charged particle telescope provide measurements of both charged-particle dose and the LET spectrum. Measuring the LET spectrum allows for determination of radiation quality factors in various weighting schemes, including the ICRU 1990 quality factor and those proposed by NASA specifically for evaluation of health risks in space. We will present results for dose and dose equivalent, both from the cruise to Mars and from the first 200 sols on the Martian surface. The contributions of neutrons to the dose and dose equivalent on the surface have also been determined and will be presented. We will briefly discuss the implications of the measurements for human exploration, in the context of NASA Design Reference Mission scenarios.

Supported by NASA (Human Exploration and Operations Mission Directorate) under Jet Propulsion Laboratory (JPL) subcontract 1273039 to the Southwest Research Institute and in Germany by the German Aerospace Center (DLR) and DLR's Space Administration, grant numbers 50QM0501 and 50 QM1201, to the Christian Albrechts University, Kiel.
Symposium II: Suborbital Microgravity Research
Wednesday, November 6, 2013 (8:00 am – 10:00 am)

[S2.1] Space Biology in the Suborbital Realm. Robert J. Ferl1,2
Matthew Bamsey2, Fionna Denis3, Thomas Graham4, Lawrence Rasmussen1,3,4, Eric Schultz3, Natasha Sng3, Agata Zupanska3, Anna-Lisa Paul1, University of Florida, Horticultural Sciences, Program in Plant Molecular and Cellular Biology and
2Interdisciplinary Center for Biotechnology Research, Gainesville, FL 32611. 3Authors in alphabetical order, 4Kennedy Space Center.
Contact information: robferl@ufl.edu

Suborbital flights offer new access to spaceflight conditions, conditions that are relevant to exploring adaptive processes important biology in extraterrestrial exploration. It is important that space biologists be aware of the number and capabilities of suborbital platforms in order to take full advantage of existing and future opportunities – such that appropriate biological questions can be developed for suborbital applications. The purpose of this presentation is to discuss some of the platforms available to biologists, and to examine some aspects suborbital experiments and approaches.

It is well established that organisms engage changes in gene expression to cope with spaceflight, and these molecular data provide insights into how terrestrial organisms acclimate to this novel environment. There is a large and growing amount of transcriptome data available from both Space Shuttle and the ISS experiments. We now also have gene expression data for Arabidopsis from parabolic flight and other high performance aircraft, all as part of a progression of experiments ranging to true suborbital spaceflights. Broadly considered, these data suggest that changes in signal transduction and specific gene expression are central to spaceflight physiological adaptation; yet there are large gaps in knowledge about gene expression among the various relevant flight regimes, as there are differences in response between short term parabolic flights and ISS flights.

Suborbital flights with 6-8 minutes of microgravity represent an opportunity to fill those gaps with key information on the transitional adaptations to microgravity. We will describe approaches to conducting gene expression studies in real time on true suborbital spaceships, as well as aircraft capable of replicating or simulating various aspects planned actual suborbital flight profiles.

This work was supported NASA NNX07AH270 - Transgenic Plant Biomonitor of Spaceflight Exposure – Telemetric Data Collection, NASA NNX10AM01H – Crew-Assisted and Crew-Autonomous Biological Imaging in Parabolic and Suborbital Vehicles, UF/SRI Space Research Initiative - Pathfinder biology in the suborbital realm.

[S2.2] Next-Gen Suborbital Spaceflight Research and Education Opportunities. S. Alan Stern, Southwest Research Institute, Boulder, CO, USA.

An era of routine human suborbital spaceflight is soon to dawn with the advent of several new-generation vehicles capable of carrying crew, experiments, and test subjects on research flights to apogees of 100–140 km, at breakthrough prices in the range of $100K-$200K per experimenter. These vehicles will have useful microgravity free-fall times of 3–4 minutes with <10^-3 g quality microgravity; in both quantity and quality, these attributes are order of magnitude superior to parabolic aircraft flights. Eventually, suborbital vehicles are expected to launch hundreds of experiments per year — opening important applications in atmospheric science, materials and fluids research, human spaceflight physiology, technology testing, and education/public outreach. I will discuss the capabilities of the coming next-gen suborbital era and point out the potential for various kinds of research.

[S2.3] An Experimenter’s Experiences in Early Commercial Suborbital Spaceflight Launches. Steven H. Collicott2, School of Aeronautics and Astronautics, Purdue University, West Lafayette, IN.

The emerging commercial sub-orbital rocket industry in the US presents new opportunities for research and education missions. Some companies have been publicized by the world’s media, others are lower-profile, and one is especially quiet. Some companies were created for the space tourism market and others have no current plans to fly humans at all. Most companies already have a Payload Users Guide published at their web sites.

The time for experimenters to take note of this new industry is now because in early 2013 a number of these companies were already operational or in flight test phase of their business development. If instead millions of dollars or Euros one could spend several tens of thousands to purchase a flight, then many more researchers could afford low gravity testing and research. All rocket companies seek to provide at least 3 minutes of high-quality weightless test times from 60km to 100km and back to 60km.

Purdue has been fortunate to have secured numerous launches for small payloads during these developmental and early operational years of the industry. Lessons from these launches include lessons in design, payload environment, procedures, launch site infrastructure, and travel preparations. Thoughts on proposing to future FOP announcements will be shared.

Student team travel to launches partially supported by NASA grant NNX10AU95G from the Flight Opportunities Program.


Commercial suborbital flight offers investigators and educators a compelling opportunity to access microgravity and high-altitude environments for research, development, and outreach activities. Blue Origin’s New Shepard system is designed to carry payloads and/or people to altitudes of over 350,000 feet, providing 3-4 minutes of milli-g accelerations. A custom Cabin Payload System is available for mechanical, electrical, data, and thermal interfaces; or investigators may provide their own.

Blue Origin’s reusable space systems are designed to enable private access to space at dramatically lower cost and increased reliability. A Vertical Takeoff and Vertical Landing (VTVL) architecture ensures short timelines from launch to recovery. A private launch facility provides flexibility for experiment operations pre-flight and post-flight. And ultimately, New Shepard is designed to carry people, enabling human-tended research with a payload specialist in the loop, or a research subject flying to space.

This session will introduce investigators to New Shepard’s capabilities for supporting a wide range of life, physical, and microgravity sciences. Opportunities for maturing hardware and science for orbital investigations will be examined, and open funding channels will be discussed.
[S2.5] Research Opportunities On Board Virgin Galactic’s
SpaceShipTwo. K. R. Stephens1, W. J. Pomerantz2. 1Virgin Galactic, LLC, Mojave, CA, USA. 2Virgin Galactic, LLC, Pasadena, CA, USA.

Virgin Galactic is building the world’s first commercial spaceline. Our suborbital spaceflight system consists of two vehicles: WhiteKnightTwo and SpaceShipTwo. WhiteKnightTwo is a four-engine, dual-fuselage jet aircraft capable of high-altitude heavy lift missions, including, but not limited to fulfilling its role as a mothership for SpaceShipTwo, an air-launched, suborbital spaceplane capable of routinely reaching outer space. In conjunction, these two vehicles allow access to space and to regions of the atmosphere ranging from the troposphere to the thermosphere; additionally, they provide extended periods of microgravity in a reliable and affordable way. SpaceShipTwo, with a payload capacity of up to 1,300 lbs. (~600 kg), features payload mounting interfaces that are compatible with standard architectures such as NASA Space Shuttle Middeck Lockers, Cargo Transfer Bags, and server racks, in addition to custom structures. Each dedicated research flight will be accompanied by a Virgin Galactic Flight Test Engineer, providing an opportunity for limited in-flight interaction. In addition, tended payloads — a flight that includes the researcher and his or her payload — are also an option. At a price point that is highly competitive with parabolic aircraft and sounding rockets and significantly cheaper than orbital flights, SpaceShipTwo is a unique platform that can provide frequent and repeatable research opportunities. Suborbital flights on SpaceShipTwo offer researchers several minutes of microgravity time and views of the external environment in the upper atmosphere and in outer space. In addition to serving as an important research platform in and of itself, SpaceShipTwo also offers researchers a means to test, iterate, and calibrate experiments designed for orbital platforms, including the International Space Station as well as LauncherOne, Virgin Galactic’s dedicated launch vehicle for small (~500 lbs. / ~225 kg) satellites. Flights on SpaceShipTwo can be booked directly through Virgin Galactic. Various funding sources may be available for the research, including through NASA programs such as the Flight Opportunities Program, Game Changing Development Program, or Research Opportunities in Space and Earth Science (ROSES). More information about the SpaceShipTwo research platform, including a detailed Payload User’s Guide, can be found at our website:
http://www.virgingalactic.com/research.
WORKSHOPS I-VII
See dates/times below

Monday, November 4
12:00 pm – 1:00 pm

Workshop I:
Drop Tower Workshop
Chair/Organizers: David Urban, NASA Glenn Research Center
Speakers: David Urban, and possibly others from Bremen and Japan
Overview:
Ground based microgravity facilities are an important proving ground for space experiments, ground-based research and space hardware risk mitigation. An overview of existing platforms will be discussed with an emphasis on drop tower capabilities. The potential for extension to partial gravity conditions will be discussed. Input will be solicited from attendees for their potential to use drop towers in the future and the need for enhanced capabilities (e.g. partial gravity).

Tuesday, November 5
12:00 pm – 1:00 pm

Workshop II:
CASIS – The ISS National Laboratory
Chair/Organizers: Duane Ratliff (CASIS)
Speakers: Duane Ratliff, Cindy Bouthot and Warren Bates
Overview:
CASIS’ mission is to develop a commercial market interest for utilizing the ISS as a National Laboratory that will enable research, technology development, and ultimately the development of products and new knowledge that will have a direct and measurable impact on the overall benefit of mankind. This mission is critically different from NASA’s and focuses on terrestrial application, attracting a novel commercial user base, and creating a platform that enables application and moving fundamental discoveries far to the right of the research spectrum. As a result of these differences, the model in which CASIS must generate business opportunities is one that is strikingly different from the traditional government funded grant model. These aspects will be compared and contrasted and CASIS’ overall approach will be discussed in order to generate discussion and more importantly a broad understanding among the research community.

Wednesday, November 6
10:30 am – 12:00 pm

Workshop IV:
Education and Outreach Workshop
Chair/Organizers: Kim Slater (CSS-Dynamac) and Susan Mayo (NASA ISS Program Office)
Speakers: Angela Munoz (Lakeland High School, Polk County, FL); Wanda Jones (Hospital Homebound School, Orange County Public Schools, FL); Mike Dixon (Controlled Environment Systems Research Facility, University of Guelph); David Rabkin (Farinon Director of Current Science and Technology, Museum of Science, Boston, MA)
Overview:
The following Space Education programs will be presented:

- **The Space Microbe Invasion:** “The Space Microbe Invasion: To Eat or Not to Eat?” workshop participants will work with ISS Faculty Fellows, Dr. Wanda Jones, and Ms. Angela Munoz as they demonstrate their classroom lesson that examines the most effective method of controlling bacterial populations growth on food. This hands-on instructional activity conveys gravitational research on board the International Space Station (ISS). The activity should engage the participants to think about how a student can take on real roles as specific types of scientist solving real life issues, while teachers benefit from the lesson use of science standards and common core standards. (Speakers: Munoz and Jones)

- **Tomatosphere: A Space Science Outreach Project:** The Tomatosphere project began in 2000 with the launch of the first batch of tomato seeds on the space shuttle for Canadian astronaut, Marc Garneau’s final space mission. Once returned to Earth the seeds were circulated among primary and secondary school classes across Canada where seed germination rates were tested against Earth-based controls. The project has continued annually since then with a variety of seed treatments including simulated space exposure and real space exposure on the ISS for extended periods. The related curriculum content of the science program available to teachers on the web site includes space science, plant science, nutrition and the scientific method of investigation. The award-winning project has become the most successful science promotion activity in Canadian history. (Speaker: Dixon)

- **Museum of Science in Boston:** "How to reflect on your own research and develop tools that can propel your message" - With an annual audience of 1.5 million visitors, the Museum of Science (MOS) Boston is an innovative leader in science education. The MOS Current Science and Technology (CS&T) team surveys recent achievements in science and technology and carefully articulates stories to make the profound accessible to adults and children alike. With ISS research, they find ways to connect meaningful on-orbit research with everyday life on Earth. The MOS will help us reflect on our own research and develop tools that can propel our own messages forward.
Thursday, November 7  
12:30 pm – 2:00 pm

**Workshop V:**
**Microscopes on the ISS Workshop**

Chair/Organizers: Fred Kohl, Ronald Sicker, William Meyer, Patricia Parsons-Wingerter (NASA Glenn Research Center)

Speakers: Ronald Sicker and William Meyer; JAXA representative; ESA representative; NanoRacks representative

**Overview:**
At least five general purpose and specialized microscopes are resident on the ISS for use by life, space biology or physical science experiments. Speakers will describe the capabilities of the various microscopes and highlight opportunities for their use.

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Friday, November 8  
10:30 am – 12:00 pm

**Workshop VI:**
**Life Science NRA Writing Workshop**

Chair/Organizers: Howard Levine (NASA Kennedy Space Center)

Speakers: Howard Levine; David Tomko (NASA Headquarters); Jeff Smith (NASA Ames Research Center)

**Overview:**
This workshop will familiarize the Life Science community with the goals, requirements and selection criteria for NASA Research Announcements for both ground investigations and spaceflight experiments. An overview of the primary hardware available for ISS investigations will also be presented.

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**Workshop VII:**
**Open Source Physical Science Workshop**

Chair/Organizers: Fran Chiaramonte (NASA Headquarters) and Fred Kohl (NASA Glenn Research Center)

Speakers: Fran Chiaramonte; Ben Henrie (NASA Marshall Space Flight Center); James P. Patton Downey and Brian Motil (NASA Glenn Research Center)

**Overview:**
The new Physical Science (PS) Informatics System will provide global access to all past, present and future ISS PS experimental data. This will promote an open source approach to scientific data analysis and become a gateway to hundreds of new ISS based investigations which will define the next generation of ISS experiments. The subsequent multiplication of investigators with data access will greatly enhance discovery and innovation. Proposals, based on experimental data in the PS Informatics System, will be solicited. Future flight investigations will be identified through NASA sponsored activities such as the materialsLAB workshop.
Monday, November 4
5:00 pm - 5:30 pm

Information Session I:
Research Opportunities for Materials and Fluids
Chair/Organizers: Fran Chiaramonte (NASA Headquarters) and Fred Kohl (NASA Glenn Research Center)
Speakers: Fran Chiaramonte; Ben Henrie (NASA Marshall Space Flight Center); James P. Patton Downey and Brian Motil (NASA Glenn Research Center)

Overview:
A newly developed open source approach will be implemented for scientific data analysis of past, present and future experiments using an informatics system. This will become a gateway to hundreds of new ISS based investigations which will define the next generation of ISS experiments. For Materials Science, the upcoming materialsLAB Workshop in January 2014 will identify relevant areas of research for future solicitations. A similar path will be followed for Fluid Physics.

Tuesday, November 5
12:00 pm – 1:00 pm

Information Session II:
Market Driven Research in Space – A Panel Discussion
Chair/Organizer: Tony Gannon, Space Florida
Speakers: Frank DiBello (Space Florida), Dr. Sam Durrance (Florida Institute of Technology), Dr. Siobhan Malany (Sanford-Burnham Medical Research Institute) and Rich Pournelle (NanoRacks)

Overview:
The Microgravity environment offers a unique economic and beneficial opportunity for applications such as - crystal growth, Earth observation satellites, medical and agricultural research. NewSpace vehicles and brokers are providing access to the ISS - are we finally at the dawn of an era where humankind can truly benefit from access to space and all is has to offer?

Tuesday, November 5
5:00 pm - 5:30 pm

Information Session III:
Express Rack Facility
Chair/Organizer: Robert Corban, NASA Glenn Research Center
Speaker: Lee Jordan, NASA Marshall Space Flight Center

Overview:
Workshop to provide an overview for conducting research on the International Space Station using the Microgravity Science Glovebox (MSG) Facility. The unique design of the MSG allows it to accommodate science, technology and biological investigations in a workbench type environment within an enclosed barrier working volume. Modifications to the MSG facility are currently under way to expand the capabilities and provide for new investigations involving Life Science research. An overview of the MSG facility, MSG accomplishments, and an future upgrades that are being planned to expand the ISS capabilities will be presented.

Information Session IV:
Microgravity Science Glovebox
Chair/Organizer: Robert Corban, NASA Glenn Research Center
Speaker: Sean Thompson, NASA Marshall Space Flight Center

Overview:
Workshop to provide an overview for conducting research on the International Space Station using the EXPRESS Rack Facilities. Eight ISS “EXPedite the Processing of Experiments to Space Station” (EXPRESS) Rack facilities provide standard resources and interfaces for the simultaneous and independent operation of multiple experiments within each rack.

Thursday, November 7
8:00 am – 9:00 am

Information Session V:
Introduction to Physical and Life Science Microgravity Research
Chair/Organizers: Simon Gilroy (University of Wisconsin – Madison) and Mike Banish (University of Alabama– Huntsville)
Speakers: Simon Gilroy, Mike Banish, Joe Tash (University of Kansas Medical Center), John Kizito (North Carolina A&T State University)

Overview:
This symposium will present a short overview of the kinds of questions being asked by life and physical scientists about how systems function in microgravity. The discussion will highlight where physical and life scientists are approaching the same questions and where the cross-disciplinary approach has impact.

Abstracts:
Introduction to Physical and Life Sciences Microgravity Research. S. Gilroy, and M. Banish. 1Department of Botany, University of Wisconsin-Madison, Madison, WI, USA, 2Dept of Chemical and Materials Engineering, University of Alabama in Huntsville, Huntsville, AL, USA.

The physics of the microgravity environment of spaceflight presents challenges to a terrestrial biology that has evolved under constant gravitation forces. The conditions of a low-gravity environment provide a unique tool with which to separate out and understand both basic physical and biological processes. These fundamental processes are often shared between physics and life science studies and there is an enormous potential for synergy where life and physical scientists cross disciplinary lines. These kinds of cross-disciplinary advances require biologists to understand how physicists approach microgravity-driven questions and vice-versa.

ASGSR provides one of the few forums where these two groups meet. This symposium will therefore present a short overview of the kinds of questions being asked by life scientists about how biological systems function in low-gravity, such as the effects of the minimization of sedimentation and changes in fluid flow behavior that are inherent in spaceflight. This introduction will be coupled to a discussion of microgravity research in the physical sciences. We will highlight where physical and life scientists are approaching the same questions and where the cross-disciplinary approach has impact.
Sperm Functions in the Space Flight Environment: Biophysics in Action at the Cellular Level. J.S. Tash, Ph.D. Dept. Molecular & Integrative Physiology, and Dept. of Urology, University of Kansas Medical Center, Kansas City, KS.

The survival of species on earth, and in long term space flight, requires maintenance of fertility in both males and females. Factors that contribute to successful reproduction in humans and rodents include healthy behavioral (social), endocrine, gonadal and reproductive organ functions, normal gametogenesis, as well as proper gamete functions and interactions. An earlier mating attempt in space flight using male and female rats on the 18-day US/Russian COSMOS 1129 satellite flight failed to show evidence of mating, fertilization, or pregnancy. However, whether the lack of evidence in space flight was due physical factors, or to female or male infertility factors was not be directly determined. Female factors: More recently on Space Shuttle flights STS-131, STS-133, and STS-135, we found that female ovarian functions and estrogen signaling in female mice were significantly down-regulated after only 12-15 days in orbit. However, whether this observation is reversible remains to be assessed. Male factors: Sperm motility and its interactions with the egg are critical biophysical processes necessary for successful fertilization. Early sounding rocket experiments demonstrated that sperm motility (driven by motor proteins in the sperm tail) is accelerated in microgravity compared to 1G. On the recent 30-day US/Russian BION M1 flight we report here that sperm that completed the last half of their development in space flight showed near-normal motility when assessed shortly after landing. Whether the sperm were fertile is not known. On STS-81 and 84, we found sperm motility (driven by motor proteins in the sperm tail) is accelerated in microgravity compared to 1G. On the recent 30-day US/Russian BION M1 flight we report here that sperm that completed the last half of their development in space flight showed near-normal motility when assessed shortly after landing. Whether the sperm were fertile is not known. On STS-81 and 84, we found that the signal transduction coupled to sperm flagellar motor activation was more rapid in µG than in 1G, but that the response to chemotactic egg factors was delayed. Sperm motility and egg fertilization are remarkably sensitive to changes in gravitational force, fluid density and viscosity. As such, they are a remarkable model to elucidate the interface between physics and biology at the cellular level. Future studies to be conducted on the ISS will examine the coordinated relationship between metabolic, signal transduction, morphologic and motility process in sperm essential for fertility at the cellular level in the male. (Funded by multiple NASA grants to JST).
An effective means to reducing the size and weight of future space vehicles is to replace present mostly single-phase thermal management systems with two-phase counterparts. By capitalizing upon both latent and sensible heat of the coolant rather than sensible heat alone, two-phase thermal management systems can yield orders of magnitude enhancement in flow boiling and condensation heat transfer coefficients. Because the understanding of the influence of microgravity on two-phase flow and heat transfer is quite limited, there is an urgent need for a new experimental microgravity facility to enable investigators to perform long-duration flow boiling and condensation experiments in pursuit of reliable databases, correlations and models. This presentation will discuss recent progress in the development of the Flow Boiling and Condensation Experiment (FBCE) for the International Space Station (ISS) in collaboration between Purdue University and NASA Glenn Research Center. Also discussed are new models and correlations that have recently been developed for the prediction of pressure drop and heat transfer coefficient for both flow boiling and condensation, as well as criteria for negating the influence of gravity on critical heat flux in flow boiling.

Supported by the National Aeronautics and Space Administration (NASA) under grant no. NNX13AB01G.

[C1.1] Flow Boiling and Condensation Experiment (FBCE) for the International Space Station – Predictive Tools. Issam Mudawar1, Mohammad M. Hasan2. 1Purdue University Boiling and Two-Phase Flow Laboratory (PU-BTPF), Mechanical Engineering Building, 585 Purdue Mall, West Lafayette, IN 47907, U.S.A., Phone: (765) 494-5705, Fax: (765) 494-0539, Email: mudawar@ecn.purdue.edu; 2NASA Glenn Research Center, Fluid Physics and Transport Branch, MS 77-5, 21000 Brookpark Rd, Cleveland, OH 44135, U.S.A., Phone: (216) 977-7494, Fax: (216) 433-8050, Email: mohammad.m.hasan@nasa.gov.

An experimental investigation has been carried out to determine the effect of varying gravity level on flow boiling fluid structure and visualization in a 6 mm ID silicon flow channel. A capacitance void fraction probe was also utilized to better understand gravity’s effect upon both latent and sensible heat of the coolant rather than sensible heat alone. Two-phase thermal management systems can yield orders of magnitude enhancement in flow boiling and condensation heat transfer coefficients. Because the understanding of the influence of microgravity on two-phase flow and heat transfer is quite limited, there is an urgent need for a new experimental microgravity facility to enable investigators to perform long-duration flow boiling and condensation experiments in pursuit of reliable databases, correlations and models. This presentation will discuss recent progress in the development of the Flow Boiling and Condensation Experiment (FBCE) for the International Space Station (ISS) in collaboration between Purdue University and NASA Glenn Research Center. Also discussed are new models and correlations that have recently been developed for the prediction of pressure drop and heat transfer coefficient for both flow boiling and condensation, as well as criteria for negating the influence of gravity on critical heat flux in flow boiling.

Supported by the National Aeronautics and Space Administration (NASA) under grant no. NNX13AB01G.


An experimental investigation has been carried out to determine the effect of varying gravity level on flow boiling fluid structure and heat transfer. Flow boiling tests were conducted on Zero-G’s 727 and Novespace’s A300 aircraft using an infrared thermometry technique to measure simultaneous local heat flux and flow visualization in a 6 mm ID silicon flow channel. A capacitance void fraction probe was also utilized to better understand gravity’s effect on flow structure. Experimental conditions include subcooled and saturated fluid at the test section inlet and mass fluxes between 50 and 350 kg s^-1 m^-2. Data collected shows that the effect of gravity on flow regime is dependent on the system conditions and is coupled with the observed heat transfer coefficient. At lower mass fluxes, both saturated and subcooled flows exhibit churn flow characteristics in terrestrial gravity (1g) and hypergravity (1.8g). In microgravity (0.01g), the flow transitions to either bubbly flow with larger bubble diameters, or annular flow. For higher mass fluxes, annular flow is present for all gravity levels with the vapor-liquid interface becoming smoother in microgravity. The observed heat transfer coefficient is shown to be related to the behavior of the flow as the gravity level changes.

This work is supported by NASA grants NNX11AN49H and NNX09AK39A. Collaboration with CNES and Novespace is also gratefully acknowledged.

[C1.3] Single Bubble Dynamics under Microgravity Conditions. E. Aktino1, G.R. Warrier1, and V.K. Dhir2. 1Henry Samueli School of Engineering and Applied Science, UCLA, Los Angeles, CA, USA.

Single bubble dynamics during nucleate pool boiling was experimentally investigated in the international space station where gravity level was of the order of 10^-7 ge. The test liquid used in the experiments was Perfluoro-n-hexane and the test surface was made of a polished aluminum disc 89.5 mm in diameter and 1 mm thick with artificial cylindrical cavities placed at predetermined locations. Heating was provided by strain gages located on the backside of the disc and controlled to maintain a constant surface temperature. The effects on bubble dynamics of a wide range of pressures, liquid and surface temperatures, and dissolved gas content were tested. Two dimensional axisymmetric numerical computations that account for time-varying system pressures and wall temperatures as well as the presence of dissolved gas were carried out to simulate the experimental conditions. Simulated growth and wall heat transfer rates are in good agreement with the experimental results. The simulations show that the noncondensable gas accumulates at the top of the bubble as it grows, thus reducing the effect of subcooling and inducing capillary flow around the bubble due to the varying surface tension force along the liquid-vapor interface. Theoretical bubble departure diameters calculated by correlations as well as numerical simulations done previously all predict larger diameters than what the boiling chamber would allow for. The results of the experiments confirmed that single bubbles did not depart and remained in contact with the surface independent of system parameters.

This work was supported under the NASA Microgravity Fluid Physics Program.

[C1.4] CVB: The Constrained Vapor Bubble Capillary 40 mm Fin Experiment on the ISS. Peter C. Wayner, Jr., Akshay Kundan and Joel L. Plawsky. Department of Chemical and Biological Engineering, Rensselaer Polytechnic Institute, Troy, NY, USA.

The Constrained Vapor Bubble (CVB) is a prototype for awickless heat pipe based on interfacial phenomena that was studied in the microgravity environment of the International Space Station. The use of interfacial free energy gradients to control fluid flow naturally leads to simpler and lighter heat transfer systems because of the absence of mechanical pumps. These “passive” engineering systems are ideal candidates for the space program. In this context, “passive” refers to the natural pressure field for fluid flow due to changes in the intermolecular force field under an imposed heat flux. This force field is a function of the shape, temperature, and composition of the system. It is both an experiment in basic thermal fluid science and a study of an extended fin heat exchanger. The CVB consists of a relatively simple setup - a quartz cuvette with sharp corners partially filled with pentane as the working fluid. Along with temperature and pressure measurements, the two-dimensional thickness profile of the pentane menisci formed at the corners of the cuvette were determined using the Light Microscopy Module (LMM) in the Fluids Integrated Rack (FIR). The flow processes within the device were notified.
Concurrent Session 2: Fundamental Physics 1 – Atomic Clock Ensemble in Space (ACES)

Session Chair: Ulf Israelsson, NASA Jet Propulsion Laboratory
Time: Monday, 2:00 pm – 3:30 pm


Atomic clocks and atom interferometers are precise instruments for the measurements of tiny variations in time and distance and for the measurement of faint forces. As such, they can be used to test Einstein's theory of general relativity to high accuracy. Space offers the additional advantage of long free-propagation distances and large variations of the gravitational potential (space-to-ground), providing unique experimental conditions, not accessible in a ground-based laboratory, to exploit the potential of these instruments. The ESA program is developing high-performance clocks and interferometers for testing fundamental physics on the ISS. Operated on-board the International Space Station, the ACES (Atomic clock Ensemble in Space) payload will distribute a clock signal with fractional frequency instability and inaccuracy of 1E-16. Space-to-ground and ground-to-ground comparisons of atomic frequency standards will be used to test Einstein's theory of general relativity including a precision measurement of the gravitational redshift, a search for time variations of fundamental constants, and tests of the Standard Model Extension. ACES is scheduled for a launch to the ISS in mid-2016. SOC (Space Optical Clocks) is developing an optical clock improving the ACES performance by a factor 10. Finally, QWEP (Quantum Weak Equivalence Principle) is studying the feasibility of an atom interferometry test of the universality of free fall on board the International Space Station. This paper will discuss the progress recently achieved on ACES, SOC, and QWEP.


PHARAO (Projet d’Horloge Atomique par Refroidissement d’Atomes en Orbit) is the cesium atomic clock of ACES (Atomic Clock Ensemble in Space). ACES is an ESA mission to demonstrate a laser-cooled atomic clock in microgravity, to precisely test general relativity, and to accurately transfer time between widely separated clocks on earth. The performance goals for PHARAO aim to achieve a linewidth as small as 0.11 Hz, an accuracy of 1E-16, and a short-term instability of 7E-16 at 1s of averaging. Demonstrating the PHARAO stability and accuracy are important goals of the ACES mission. The three largest sources of systematic uncertainty for PHARAO are the collisional frequency shift, a first-order Doppler shift, known as the distributed cavity phase shift (DCP), and the frequency shift due to the microwave lensing of the atomic wavepackets by the microwave field in the clock cavity. The form of the microwave fields in the clock and state selection cavities are needed to evaluate each of these. We have constructed large densely-meshed three-dimensional finite element models of the microwave fields. We will present our analyses of the DCP errors and Microwave Lensing. We will also describe frequency shifts due to background gas collisions, another systematic error that has contributed significantly to the accuracy budgets of terrestrial atomic clocks.

Supported by CNES, ESA,CNRS Centre National de Recherches Scientifiques, the NASA Fundamental Physics program, LNE Laboratoire National d’Essais, Observatoire de Paris, Ecole Normale Supérieure, Penn State, and UPMC Université Pierre et Marie Curie.


Comparisons between accurate atomic clocks in diverse parts of the world are presently performed using GPS and geosynchronous-satellite frequency-transfer techniques. These techniques are inadequate for comparing the best atomic clocks available today and, such comparisons are needed both to test various aspects of physical laws as well as to validate accuracy measurements on otherwise isolated clocks. The ACES mission aboard the ISS provides a fundamentally new method of comparing remotely situated clocks at heretofore unprecedented accuracies. We will discuss the practical aspects of these comparisons using the NIST atomic clock ensemble as an example. Support from NASA/NIST.


Recent development in trapping and cooling atoms has advanced atomic frequency standards and clocks to unprecedented precision and accuracy. These advanced clocks are ideal for testing a number of fundamental laws of physics. Extension of these advancements to a space-based environment can benefit both clock performance and the related science measurements. Atomic Clock Ensemble in Space (ACES) is such a mission for fundamental physics by ESA. It uses a
new generation of clocks operating in the ISS microgravity environment. A critical part of the mission’s science experiments is performing clock comparisons between space borne clocks and ground clocks around the world. JPL will be one of several ground station sites participating in the global clock comparison experiments. In this talk we will briefly review the ACES mission concept and its overall scientific objectives. We will describe JPL’s participation in the ACES project, reporting on the progress in readying the ground clock ensemble, the ground link station site preparation, and the study of using JPL’s ultra stable ground clocks for scientific investigations.

This research was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration. Support from NASA Fundamental Physics Program is acknowledged.

[C2.5] Laser Link for Space-Time Referencing. Leo Hollberg and Paul Berceau. Department of Physics, Stanford University, Stanford, CA.

A high precision two-way time- and frequency-transfer link between ground and space can be realized using frequency stabilized CW and fs lasers combined with laser communication technologies. This approach, in essence, can lift the timing precision available from high accuracy atomic clocks on the ground to orbiting platforms such as the ISS or other satellites. With precise laser time-transfer it will be possible to improve upon the current state of the art in time transfer by roughly a factor of 1000, from the current 1 to 30 ns achieved with GPS to the ≤ 1 ps level. This type of system can also provide range information and precise orbit determination. These capabilities would support and enable future scientific missions such as cold atom clocks in space, tests of General Relativity, high accuracy comparison of ground clocks around the world, searches for physics beyond the Standard Model. These capabilities would also serve the important function of enhancing the performance of existing GNSS navigation, and precision measurements in earth sciences, such as geodesy and sea level determinations.

Supported by the NASA Fundamental Physics Program.

Concurrent Session 3: Materials Science 1
Session Chair: Douglas Matson, Tufts University
Time: Monday, 2:00 pm – 3:30 pm

[C3.1] Experimental Thermodiffusion and Diffusion Coefficients Measurements in Ternary Liquid Systems Aboard the International Space Station. 1Q. Galand and 3S. Van Vaerenbergh. 1Microgravity Research Center, Université libre de Bruxelles, Brussels, Belgium.

A fundamental step in the further developments of comprehensive modelling of the diffusive processes in liquids is based on the possibility of obtaining reliable and accurate experimental data of the diffusion and thermodiffusion coefficients of multicomponent liquid systems.

In the DSC experiment [1], a transient interferometric technique was implemented aboard the International Space Station to obtain an accurate experimental determination of those coefficients for several organic liquid systems, composed of [1,2,3,4-Tetrahydronaphtalene, Isobutylbenzene and Dodecane]. Those particular species were selected as a simplified multicomponent system modelling the fluids contained in natural crude oils reservoirs. The three equimassic systems of those components were studied in the Fontainebleau benchmark [2].

During the DSC campaign, a series of five ternary systems and one binary system were studied. For each system, several experimental runs were performed, in order to quantify the reproducibility of the technique and to investigate the temperature dependence of the thermodiffusion and diffusion coefficients.

In the present paper, we provide an overview of the obtained experimental data and we discuss the results obtained under microgravity conditions. We report the thermodiffusion and diffusion coefficients for the studied systems at 25.0 °C.


This work was supported by European Space Agency and the Belgian PRODEX Sodium.

[C3.2] Experimental Verification of Criterion for Metastable Phase formation in Containerless Solidification. K. Kuribayashi1, 2, G. Nishiya3, H. Kato3 and M. S. Vijaya Kumar4. 1Shibaura Institute of Technology, Toyo, Koto, Tokyo 135-8548, Japan, 2ISAS/JAXA, Sengen, Tsukuba, Ibaraki 305-8505, Japan.

In RFeO3 (R: rare earth element), using a containerless solidification technique, we have reported the formation of the hexagonal crystal (h-RFeO3), which attracts attention as a strong candidate of a multiferroic material in recent years. Furthermore, based on the hypothesis that a phase, the entropy of which is higher than that of an equilibrium phase, we proposed a criterion for a metastable phase to be formed instead of an equilibrium phase (Entropy-Undercooling Regime Criterion, Material Science and Engineering A, 449-451 (2007) 675).

In this model, a metastable phase can be formed preferentially, if the following equation is satisfied,

$$\frac{\Delta S}{\Delta T} > \left(\frac{\Delta T}{\Delta T}\right)^{1/2}$$  \((1)\)

where $\Delta S$ and $\Delta T$ are the entropy of fusion and undercooling, and superscripts $s$ and $ms$ mean an equilibrium phase and a metastable phase, respectively. This criterion is proposed for application to materials which exhibit faceted interfaces, such as a semiconductor and an oxide. However, until now any experimental data which support the validity of this criterion has not been obtained. From this point, adopting the technique of differential thermal analysis, we aimed to verify the validity of the above-mentioned criterion for a metastable phase to be formed during containerless solidification.
Experiments using LuFeO$_3$ as a model material showed that the above-mentioned criterion is qualitatively valid.

**[C3.3] Fabrication of Multiferroic NiFe$_2$O$_4$ by Levitation Process.**

M.S. Vijaya Kumar$^1$, T. Ishikawa$^1$, Junpei T. Okada$^1$, Y. Watanabe$^2$, and K. Kuribayashi$^3$. $^1$Japan Aerospace Exploration Agency (JAXA), $^2$Advanced Engineering Services Co. Ltd., $^3$Shibaura Institute of Technology, Tokyo, Japan.

Multiferroic ferrites with the general formula MFe$_2$O$_4$ (M= divalent metal ion, e.g., Ni, Co, Cu, Zn, etc.) have attracted considerable attention in the field of electronic industry because of multiferroic characteristics, i.e., the coexistence of ferroelectricity and magnetism in one compound. Among these ferrites, nickel ferrite is one of the most versatile and technologically important ferrite materials which have great potential applications for their typical ferromagnetic properties, low conductivity, high electrochemical stability and catalytic behavior. In the present study, containerless solidification of the NiFe$_2$O$_4$ melt, where the undercooling level can be treated as of the experimental parameter, was carried out to explore the multiferroic phases using an aerodynamic levitator (ADL). The containerless levitation under deep undercooling conditions can achieve novel microstructures such as refined grain size, stable/metastable phases and glassy phases. This indicates that containerless processing is a promising technique to explore the technologically important materials using rapid solidification of an undercooled melt because it provides large undercooling prior to nucleation.

A spherical NiFe$_2$O$_4$ sample was levitated by an ADL and completely melted by a CO$_2$ laser. Then, the droplet was cooled by turning off the CO$_2$ laser. The surface temperature and solidification behavior of the levitated droplet was monitored by pyrometer and a high-speed video camera, respectively. The x-ray diffraction (XRD) and the cross sectioned scanning electron microscopy (SCM) images confirm the existence of the multiferroic NiFe$_2$O$_4$ phase. In order to confirm the thermal stability, the samples were annealed at various temperatures using thermo gravimetric and differential thermal analysis (TG/DTA). These results confirm that the formed phases are stable even after annealing at 1473 K. The magnetic properties of the as-solidified samples were studied using vibrating sample magnetometer (VSM). These results indicate that stable multiferroic NiFe$_2$O$_4$ phases solidify directly from the undercooled melt. This work was supported by the Japan Society for the Promotion of Science (JSPS), Japan.


Alumina based ceramics have wide significant applications as optical materials, biomedical materials, bio-ceramics, laser host and as phosphors, due to their refractory nature, high hardness, high strength, transparency in the infra red region, and resistant to chemical attack. Conventionally Rare earth perovskites were prepared by melting process or by sintering techniques because of their refractory nature and recently prepared through several low temperature solution routes. There is a growing demand for the alumina based glass as they possess desirable optical properties due to their isotropic nature over a wide range of compositions. In the above said routes the materials obtained will have low sinterability and is difficult to control the particle size and chemical homogeneity. Further, it is difficult to vitrify them without using the network forming compounds. Weber et al., (2010) have clearly demonstrated single and double oxide aluminate glass preparation by containerless processing and also reported the glass forming region with varying rare earth oxide in R2O3-Al2O3 system (Watanabe et al., 2012). Hence we have systematically investigated the formation of glass and crystalline ReAlO$_3$ perovskites phase from the undercooled melt by employing the containerless processing using aerodynamic levitation (ADL) furnace. Lanthanum, neodymium and samarium aluminum perovskites solidified as glass and the rest of rare earth oxides solidified as crystalline phases. Glass transition temperature, density, transparency, Refractive index, was measured for the glass phase and they show direct correlation with the ionic radii of the rare earths. The X-ray diffraction (XRD) study and the scanning electron microscopy (SEM) revealed that the resultant crystalline phase was highly crystalline and homogeneous without any impurities. Thus we have clearly demonstrated that the container less processing of preparation material is an excellent technique for vitrifying materials which has low glass forming ability and for preparation of crystalline materials, from an undercooled melt. In the present study we have developed a high quality spherical glass and crystalline Rare earth perovskite beads of dimension ~2-3 mm dia.

Supported by University of Mysore, Mysore, India and Institute of Space and Astronautical Science (ISAS), Japan Aero Space Exploration Agency (JAXA), Japan.

**[C3.5] Optimization of Novel Composite Shielding Structures Using Geant4 Toolkit.** M. Kalliokoski$^{1,3}$, R. Orava$^{4,5}$, J. Shestovskaya$^6$, G. Atxaga$^7$, T. Brander$^7$, and A. Carapelle$^{8,9}$. $^1$Sensor Center Ltd., Vantaa, Finland; $^2$Physics Department, Lancaster University, Lancaster, United Kingdom; $^3$The Cockcroft Institute, Warrington, United Kingdom; $^4$Department of Physics, $^5$Helsinki Institute of Physics, University of Helsinki, Helsinki, Finland; $^6$Tecnalia Research and Innovation, San Sebastian, Spain; $^7$Department of Applied Mechanics, Aalto University, Espoo, Finland; $^8$Centre Spatial de Liege, $^9$Department of Astrophysics, Geophysics and Oceanography, Liege, Belgium.

The main objective of the “Radiation Shielding of Composite Space Enclosures” (SIDER) project is the development of the technologies and tools required to obtain lightweight, safe, robust and reliable composite structures. Shielding enclosures for space electronic...
systems protect the sensitive components by attenuating the energy and the flux of ionizing radiation. This is done to reduce the amount of energy that is absorbed in silicon into a level that is below the maximum dose ratings of electronic components. The received radiation amount varies depending on the orbit, the altitude, the inclination and the duration of the mission. To achieve the optimum shielding with the minimum weight, these variables have to be considered in the design. Standard material that is used in the enclosures is aluminium. By replacing aluminium by composite structures allows significant mass savings. However, conventional graphite epoxy composites are not as efficient shielding materials because of their lower density. A solution is to embed high density material into the laminate. This material, typically metallic, can be dispersed in the composite using nanoparticles or as layers in the laminate. Optimal composition of the layers and their positioning in the samples were studied using Geant4 simulation toolkit. With the simulations, the effects of the full space radiation spectrum in selected orbits were studied. These results were then validated by beam tests. We will present the development of simulation tools to optimize the composite shielding materials consisting of multilayered structures and nanoparticles, compare the results with measurements and discuss about the future implementations.

Supported by funding from the European Community’s Seventh Framework Programme (FP7/2007-2013) under Grant Agreement no. 262746 (SIDER project).

Low-pressure (LP) environments are not represented on Earth, but the ability of organisms to survive under hypobaric conditions is highly relevant to the field of Astrobiology. Specifically, for a terrestrial microorganism to grow at or near the surface of Mars (i.e., forward contamination, a concern of NASA Planetary Protection regulations), it would have to overcome the hypobaric environment on the surface, which averages ~0.7 kPa. (By comparison, the atmospheric pressure at Earth’s sea level is ~101 kPa.) Results from previous experiments indicated the existence of an LP barrier for the growth of many terrestrial bacteria of ~2.5 kPa, a pressure not represented on the Earth’s surface, but still 3-4x higher than exists on the surface of Mars. To test the hypothesis that microbes could evolve the ability to grow better at LP, we propagated wild-type Bacillus subtilis strain WN624 for 1,000 generations at 5 kPa, a pressure at which it grows very poorly, and isolated a strain called WN1106 that showed increased growth at 5 kPa, as well as an increased fitness at 5 kPa compared to the WN624 ancestral strain. Whole genome re-sequencing using the Illumina platform was conducted on both ancestor and the LP-evolved strain and the resulting genomes and compared to the reference genome of B. subtilis strain 168. To date, bioinformatics analysis of the data have located 6 single nucleotide polymorphisms (SNPs) causing missense mutations, and one Insertion / Deletion mutation (InDel) located in coding regions of strain WN1106’s genome; these mutations have all been confirmed by PCR amplification and Sanger sequencing. Mutation analyses, competition experiments, and transcriptome analyses are being utilized to reveal the adaptive role of these genes in LP growth of Bacillus subtilis.

This research is supported by NASA grant NNX08AO15G to W.L.N. and a NASA Earth and Space Science Fellowship (NESSF) fellowship to S.M.W.


Giant yeast colonies are complex, stratified 3-D structures, used in tumor modeling studies, in which diverse redox states can be induced for study of drug metabolism pathways. The promoter Msn-4 both activates a unique set of Saccharomyces cerevisiae genes including SSA-4 and YIL052C in microgravity and mediates survival of giant yeast colonies. As growing yeast colonies deplete available nutrients, they alkalize the supporting agar, which triggers ammonia secretion. Ammonia induces colony stratification into lower apoptotic cells and upper growing cells. Microgravity is likely to impact this signaling process as convection of volatile gases like ammonia is gravity-dependent. We evaluated the effect of microgravity emulated by clinorotation on SSA-4 and YIL052C gene expression and Msn-4 dependence in giant yeast colonies. Yeast strains were molecularly engineered with eGFP gene expression reporters for SSA-4 and YIL052C with and without deletion of the Msn-4 promoter. Giant yeast colonies were grown on agar for 15 days under static and clinorotation conditions and analyzed for gene expression (eGFP) and cell death (propidium iodide) by flow cytometry (relative fluorescence units, N=6, mean ± SD; two-tailed t-test). Rotation significantly decreased SSA-4 gene expression (static = 416 ± 9 vs. rotating 299 ± 14; p = 7E-9) but increased YIL052C gene expression (static = 118 ± 6 vs. 299 ± 9; p=2E-15). Slowing the ammonia-dependent colony life cycle by increasing the thickness of the nutrient agar reversed the direction of the gene expression effects on YIL052C (static = 547 ± 33 versus rotating 438 ± 16; p = 2E-5) but not on SSA-4 (static = 552 ± 45 vs. 461 ± 23; p=0.001). Deletion of the Msn-4 promoter completely abolished SSA4 and YIL052C gene expression under all conditions. Rotation increased cell death in wild-type yeast from 13.3 ± 1.6% in static colonies to 17.2 ± 1.0% in rotated colonies (p=0.0004). Clinorotation and nutrient supply (agar thickness) affect gene expression and cell death in giant yeast colonies. A direct link to ammonia signaling can now be tested with ammonia pathway gene deletions and provision of exogenous ammonia, to provide a broad range of redox states for drug metabolism studies.

Supported by NASA.

[C4.3] Development of Multiple Antibiotic Resistance in Opportunistic Pathogens Exposed to Spaceflight: the BRIC-18 mission to ISS. W.L. Nicholson1, R. Narvel1, R. Moeller2, and P. Fajardo-Cavazos.1 1Department of Microbiology and Cell Science, University of Florida, Space Life Sciences Laboratory, Merritt Island, FL, USA, 2Institute for Aerospace Medicine, German Aerospace Center (DLR), Cologne, Germany

Increased pathogenicity of opportunistic bacteria during long-term spaceflight is considered an astronaut risk. Because only a limited pharmacy can be carried on long-duration missions, the development of resistance to multiple antibiotics is a concern for mission planning. The BRIC-18 experiment is planned to address the hypothesis that growth in the human spaceflight environment results in elevated frequency of mutation to multiple antibiotic resistance. Using the model organisms Bacillus subtilis strain 168 and Staphylococcus epidermidis strain ATCC 12228, a harmless human commensal organism closely related to S. aureus, the BRIC-18 mission will test the hypothesis that exposure to the human space flight environment increases the frequency of mutation to simultaneous resistance to the antibiotics rifampicin (RIF) and trimethoprim (TMP). Ground-based studies are currently being performed using rotating High Aspect Ratio Vessels (HARVs) to simulate microgravity. Spaceflight experiments will be performed on the ISS during the Dragon III/BRIC-18 mission currently scheduled for launch in early December 2013, using Biological Research in Cansisters-Petri Dish Fixation Units (BRIC-PDFUs) with asynonomous ground controls. To date, growth and baseline mutation frequencies to RIF and TMP have been established for both organisms; Science Verification Tests (SVTs) in BRIC-PDFUs have been completed; and Procedure Verification Tests (PVTs) are underway. Results from the pre-launch ground-based studies and verification testing will be presented.
[C5.1] Shuttle Flight STS-135: Microgravity and Sclerostin on Proximal Tibia Stiffness and Structural Efficiency in Mice. A.G. Lau1, C.T. Smith1, E.W. Livingston1, A.B. de Rosa1, E.W. Lai1, L.C. Bowman1, L.S. Stodieck2, A. Hanson3, T. Pruitt4, R. Ellman5, J. Spatz6, C. Paszty7, V.L. Ferguson7, M.L. Bouxsein7, T.A. Bateman1. 1Biomedical Engineering, University of North Carolina Chapel Hill; 2Mechanical Engineering, University of Colorado at Boulder; 3Wyle; 4Clemson University; 5Beth Israel Deaconess Medical Center; 6Harvard-MIT Division of Health Sciences and Technology; 7Amgen.

Introduction: Skeletal unloading during spaceflight reduces bone volume and bone mineral density; however, to what extent this loss translates to functional changes in bone is not well documented. This study employs subject-specific finite element modeling (FEM) 9-week old mice flown on STS-135 to assess changes in bone compressive stiffness and structural efficiency in the proximal tibia from 13-days of microgravity and a Sclerostin antibody (Scl-Ab) countermeasure.

Methods: Two groups of mice were flown on STS-135, receiving either Scl-Ab (n=15) or placebo (n=15). Corresponding ground controls were maintained for the duration of the flight (n=15). Finite element models were meshed from microCT image data to assess stiffness and structural efficiency (stiffness per amount of bone volume). To account for growth during the study, baseline data were obtained by euthanizing a group of age-matched mice (9-weeks).

Results: Whole Bone: Spaceflight reduced both bone stiffness (-35%) and structural efficiency (-22%) in placebo mice. Scl-Ab treated flight mice showed no loss of bone stiffness, but had a -9% reduction in structural efficiency. Ground mice receiving Scl-Ab had increases in both stiffness (+60%) and efficiency (+13%). Interestingly, while the Baseline and Ground (placebo) mice had different compressive stiffness, they had the same structural efficiency. This suggests that the level of gravitational loading drives the structural efficiency of bone.

Trabecular Bone Analysis: Spaceflight reduced both trabecular bone stiffness (-45%) and structural efficiency (-19%) in placebo mice. This loss was mitigated by Scl-Ab, which improved both stiffness (+28%) and efficiency (+20%). In the ground mice, Scl-Ab increased both stiffness (+108%) and structural efficiency (+12%).

Cortical Bone Analysis: Spaceflight reduced both cortical bone stiffness (-32%) and structural efficiency (-21%) in placebo mice. Scl-Ab fully mitigated loss of cortical bone stiffness, but was unable to maintain cortical bone efficiency (-12%).

Conclusion: Spaceflight reduced both bone stiffness and structural efficiency. Scl-Ab countermeasure mitigated the loss of bone stiffness, however, did not fully mitigate loss of bone structural efficiency. On the ground, Scl-Ab increased both stiffness and structural efficiency. Future work could look at effects of combining Scl-Ab and exercise loading during spaceflight on structural efficiency and overall stiffness of bone.
STS-135 to assess bone stiffness changes from spaceflight and sclerostin antibody (Scl-Ab).

Thirty mice were flown on Space Shuttle Flight STS-135 for 13-days (FL). Half the mice were treated with vehicle (n=15) and half were treated with a Scl-Ab (n=15). Corresponding ground control (GC) groups were similarly treated. Subject specific FE models were meshed from each microCT mouse image (down sampled from 10 to 20μm resolution) for a 3.25mm proximal femur segment taken of the top of the femoral head. Bone was segmented using the identical threshold previously used in the microCT analysis of the STS-135 femurs. All bone elements were modeled as linear elastic (E=10GPa, v=0.3). A 50μm downward displacement was applied to the entire femoral head in order to isolate loads to the femoral neck. This loading configuration differs from the corresponding mechanical testing performed on the femurs. The mechanical tests are susceptible to significant deformations in the femoral head in addition to the femoral neck. FEM of the proximal femur found a 10% decrease in stiffness in the FL mice compared to the GC mice. Scl-Ab treatment resulted in an increased stiffness by 20% in the FL and 23% in the GC. Linear regression found significant correlations (P<0.01) between the FEM stiffness and the femoral neck stiffness, fracture load, and force at maximum load found from mechanical testing. The unloading environment of microgravity caused a significant loss of femoral neck stiffness in the proximal femur. Scl-Ab prevented the loss of bone strength, and increased femoral neck stiffness in both FL and GC mice. The absolute stiffness values from FEM were greater than those measured with mechanical testing due to the different boundary conditions and the low bone density in the femoral head observed from microCT. The experimental boundary conditions must be considered when interpreting femoral neck strength.

Supported by BioServe, AMGEN Inc. and National Space Biomedical Research Institute: PF03003 through NASA NCC 9-58.

Concurrent Session 6: Fluid Physics 2
Session Chair: Peter Wayner, Jr., Rensselaer Polytechnic Institute
Time: Monday, 4:00 pm – 5:00 pm

[C6.1] Performance Studies of a DynaSwirl™ Phase Separator for Space Applications. Xiongjun Wu, Greg Loraine, Jingsen Ma, Chao-Tsung Hsiao, and Georges L. Chahine. DynaFLOW, INC., 10621-J Iron Bridge Road, Jessup, MD 20794, USA.

The limited amount of liquids and gases that can be carried to space makes it imperative to recycle and reuse these fluids. Development of a phase separator that is capable of efficiently and reliably separating gas-liquid mixtures of both high and low void fractions in a wide range of flow rate is of great interest for space applications. Over the past few years, DynaFLOW, INC. has been actively developing a passive phase separator based on its DynaSwirl™ nozzle technology. The swirl chamber comprises two concentric cylindrical chambers. Fluid introduced in the space between the two cylinders enters the inner cylinder through several tangential inlet slots to generate a strong swirling flow. This configuration is able to generate a cavitating vortex core even at low flow rates. By combining swirl, cavitation, and rectified gas diffusion, the DynaSwirl™ phase separator is capable of forcing gas out of very low void fraction mixture into the central gaseous core of the vortex for separation. After successful demonstrations in two NASA reduced gravity flights in August 2009 and May 2012, systematic ground experiments were conducted to better understand the reduced gravity flight experiment data and optimize the phase separator for an upcoming reduced gravity flight test in September 2013. Effects of major design parameters, such as the size, location, and layout of injection slots and exit orifices, etc., on the swirling flow behavior and the gas extraction performance of the phase separator were studied. In parallel, 3D numerical simulation studies were conducted to better understand the physics behind and to provide guidelines for system optimizations. This paper describes details of these studies and new results from the latest reduced gravity tests.

This work is being performed under NASA Grant No. NNX11AO76A, Mr. John B. McQuillen / Ms. Laruen M. Sharp, Project Scientists; Ms. Nancy R. Hall, Project Manager.

[C6.2] Study of Gas Core Behavior of Passive Cyclonic Two-Phase Separator for Microgravity Applications. Ming-Fang Kang, Nathaniel C. Hoyt, Adel Kharraz, Kuan-Lin Lee, Jaikrishnan Kadambi, and Yasuhiro Kamotani. Mechanical and Aerospace Engineering Department, Case Western Reserve University, Cleveland, OH, 44106 USA.

Separating gas-liquid two-phase flow is an important part of many space engineering systems. Many systems on the space station contain both liquids and gases. However, most equipment can effectively handle either gases or liquids, but not both. Phase separation is achieved on earth by gravitationally driven buoyancy forces. In space, lacking gravity, gas bubbles remain suspended in the liquid and there is a need to separate the gas from the liquid. A passive cyclonic separator has advantages over the other separation techniques due to the fact that no moving part and no external energy are needed for the separation process, which makes it reliable and attractive. The gas-liquid mixture is tangentially fed into the separator and the inertia of multiphase flow itself creates the necessary swirl action for separation. The difference of density between the phases brings the gas to the center, forming a gas core surrounded by an annular liquid film during the separating process. In such separating operation, separation efficiency is strongly influenced by the gas core behavior. The main objective of the present research is to obtain insight into physical features of the gas core behavior with respect to both single-phase and multiphase injections. Based on experimental and numerical investigations, the behavior of gas core with two-phase injection is studied. It is shown that the injection nozzle design has an important effect on the core size. A model to predict the core size is developed based on a control volume analysis. The shape stability of gas core with single-phase injection is also studied numerically. The effects of surface tension and separator geometry on the gas core stability are examined. It is shown that the core collapses when the Weber number is reduced to about unity. Finally, the results from the reduced gravity experiment flight campaign are presented in comparison with ground-based findings. The implications of the data are discussed in detail.

This work is being performed under NASA Grant No. NNX09AI31G.
1Department of Chemical and Biomolecular Engineering, University of Houston, Houston, TX, USA; 2National Center for Space Exploration Research, NASA Glenn Research Center, Cleveland, OH, USA; 3NASA Glenn Research Center, Cleveland, OH, USA.

The impact of gravity on the bubble-to-pulse transition in gas-liquid co-current down-flow through packed beds is investigated using a model based on the two-phase volume-averaged equations of motion. Experimental correlations for the frictional pressure drop under normal and vanishing gravity conditions, as well as correlations for the liquid-gas interfacial area per unit volume of bed in normal gravity are used as input to the model. Both fluids are treated as incompressible and the base state is assumed to be homogeneous with a uniform pressure drop. The latter is written as the sum of two contributions, a frictional pressure drop obtained from experimental correlations and a “hydrostatic head” that depends on the gravity level, the densities of the phases, and the average liquid holdup in the column. The liquid phase is assumed to fully wet the packing. The liquid-solid interaction force density is given by an Ergun-type equation, which is modified to account for the reduction in available void space for the liquid phase due to the presence of the gas phase. The equations of the homogeneous base state are then solved to determine the average liquid holdup and the liquid-gas interaction force density. The model predicts a decrease in frictional pressure drop and an increase in total liquid holdup with decreasing gravity levels. The model also shows, as one would expect, that the effect of gravity on total liquid holdup increases with the size of the packing. Linear stability analysis shows that, for a given liquid flow, the transition to the pulse regime occurs at lower gas flow rates as the gravity level or the Bond number is decreased, in accordance with experimental observations. Under reduced gravity conditions, the predicted transition boundaries agree reasonably well with observations for a wide range of liquid viscosities. In the case of normal gravity, good quantitative agreement is obtained for the air/water system. For more viscous liquids, the model does not yield any useful predictions as the underlying pressure drop correlations have been validated mostly for the air/water system.

Supported by Grant number NNX10AL37G from the NASA Glenn Research Center.

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**[C7.1] Optical Atomic Clocks for Space Applications.** Nathan Hinkley, Jeff Sherman, Nathaniel Phillips, Marco Schioppo, Nathan Lemke, Kyle Beloy, Marco Pizzocaro, Chris Oates, Andrew Ludlow. All authors affiliated with National Institute of Standards and Technology (NIST).

Time (or its inverse, frequency) is the most precisely measured physical quantity and therefore is used in many fundamental investigations of nature. The advent of atomic clocks based on optical rather than microwave transitions has led to a 10-100 times improvement in our clock capabilities, thereby enabling a new range of applications based on ultra-precise timing including tests of fundamental physics and relativistic geodesy. As a result, space agencies such as NASA and ESA are contemplating possible missions (e.g., space-based gravitational wave detection or satellite-based tests of Einstein’s Equivalence Principle) that capitalize on this new technology. However lab-based clocks must first demonstrate sufficient levels of performance (at or below the $10^{-17}$ level, fractionally), in terms of both stability and absolute uncertainty, for these missions to achieve their ambitious goals. Here, we report progress on a clock based on neutral atoms confined in an optical lattice, one of the most promising types of optical clocks. Our clock uses about 5000 ytterbium atoms to stabilize the frequency of resonant light near 578 nm. Due to the extremely high line Q (~$10^{14}$) that results from narrow spectroscopic signals and the large number of atoms involved, optical lattice clocks can perform with unprecedented stability. A recent comparison between two such Yb clocks has demonstrated a fractional measurement precision of less than two parts in $10^{18}$ (equivalent to 1 second uncertainty over the lifetime of the universe) for only 6 hours of averaging time. The absolute uncertainty for each of these clocks depends on how well we understand the various physical effects that can alter the clock frequency. In particular, we need to understand the shifts induced by the lattice itself as well as effects due to ambient blackbody radiation. We will present our latest efforts to reduce and characterize these shifts to a fractional uncertainty of $10^{-17}$ and below. Finally, we discuss how gravitational noise might affect lattice clock performance and possible benefits that could result from clock operation in a microgravity environment (e.g., on the International Space Station).

This research is supported in part by the NASA Fundamental Physics Program.

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1Time and Frequency Division, NIST, Boulder, CO 80305; 2T. J. Watson Laboratory of Applied Physics, Caltech, Pasadena, CA 91125.

The past decade has brought a revolution in time-keeping with the introduction of clocks operating at optical frequencies. A transformative technology in the development of optical clocks was the introduction of the self-referenced femtosecond laser frequency comb, which for the first time permitted the precise counting of individual cycles of light waves and measurement of time in units of femtoseconds ($1E-15$ s). The combination of cold-atom atomic frequency standards and optical frequency combs provides a unique platform to probe fundamental physical phenomena that include general and special relativity, local position invariance, Lorentz and CPT violation, and possible variations of fundamental constants. Indeed, several planned and proposed space missions at the ISS and elsewhere are aimed at addressing these questions using advanced atom-based sensors (e.g. ACES, SOC, QWEP, EGE, STE-QUEST). For example, ESA’s SOC program calls for access to stabilized frequency combs to realize all of its fundamental mission goals. Support of this mission (as well as others) requires the development of frequency comb technology that will be appropriate for space flight. Frequency comb technology now runs reliably in research laboratories; however, these systems still remain relatively large,

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**Concurrent Session 7: Fundamental Physics 2 – Space Optical Clock (SOC)**

Session Chair: Nan Yu, NASA Jet Propulsion Laboratory

Time: Monday, 4:00 pm – 5:00 pm
This research was carried out at the Jet Propulsion Laboratory, National Aeronautics and Space Administration. Partial support from the California Institute of Technology, under a contract with the single ion trap. micro-resonators, in addition to a compact vacuum package for the time comb and frequency comb measurement systems based on crystalline nonlinear optics in microresonators. Such microresonator combs (microcombs) can be lithographically patterned and fabricated on a single silicon chip and therefore offer revolutionary advantages beyond any other conventional laser comb technology in terms of size, reliability, power consumption, integration, and sensitivity to their environment. Using standard techniques, it now appears feasible to fabricate an entire frequency comb system on a piece of silicon that is on the order of 10 cm² and just a few hundred microns thick. I will report on experiments that explore the microcomb generation process, and that realize a microcomb optical clock. Supported by NASA Fundamental Physics, DARPA QuASAR and PULSE, and NIST.

[C7.3] Towards a Miniature Optical Clock at JPL. Wade Rellergert, Lukas Baumgartel, Ivan Grudinin, Rob Thompson and Nan Yu. Jet Propulsion Laboratory, California Institute of Technology.

Today’s most stable and accurate clocks are based on optical, rather than microwave, transitions in atoms. These optical clocks are thus poised to become the world’s new frequency standards. With the unprecedented stability and accuracy of these optical clocks comes the ability to improve navigation and radio science in deep space as well as to improve tests of some fundamental laws of physics. However, significant advances in the miniaturization of the physical size and power consumption of these clocks must be made to make them suitable for space missions. We will describe our efforts at JPL towards an end goal of a miniature clock based on an optical transition in a single trapped ¹⁷¹Yb⁺ ion. First we will describe the ongoing construction of a table-top version of the optical clock at JPL which will be useful both for the characterization of the future miniaturized version and as a ground-based clock to serve ESA’s Atomic Clock Ensemble in Space (ACES) mission. We will also describe ongoing work to miniaturize the various components necessary for an optical clock. This includes the laser stabilization and frequency comb measurement systems based on crystalline micro-resonators, in addition to a compact vacuum package for the single ion trap.

This research was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration. Partial support from NASA Fundamental Physics Program is acknowledged.

**Concurrent Session 8: Materials Science 2**

**Session Chair:** Martin Volz, NASA Marshall Space Flight Center

**Time:** Monday, 4:00 pm – 5:00 pm

[C8.1] X-RISE: X-ray Investigations under Space Environment. S. Klein¹, F. Kargl¹, and A. Meyer². ¹Deutsches Zentrum fuer Luft- und Raumfahrt (DLR), Institut fuer Materialphysik im Weltraum, 51170 Koeln, Germany.

The advent of powerful and compact microfocus X-ray sources and improvements in flat-panel detector technology made in-situ investigations of material physics processes possible not only at synchrotron X-ray sources but also in the laboratory, aboard parabolic flights, and on-board of sounding rockets. To this end, first X-ray radiography (XRR) experiments were carried out within the ESA-MAP project XRMON using modules built by Swedish Space Corporation aboard parabolic flights and the sounding rockets MAXUS and MASER. Processes previously inaccessible to the experimenter’s eye were observed. The experiments showed XRR also needs to be further developed for platforms offering longer microgravity times. To this end, we initiated the development of a compact and light-weighted XRR-insert, which is fully compatible with the Materials Science Laboratory (MSL) facility within the Materials Science Research Rack (MSRR) aboard the International Space Station (ISS). This facility was custom-built by Astrium Space Technology GmbH, Friedrichshafen, and partners and delivered to us in 2009. It has been extensively tested since then and novel cartridge based inserts have been developed for materials science studies. Further, it has been developed by us into a parabolic flight facility (X-RISE – X-ray Investigations under Space Environment) and a module (MIDAS-M – Monitoring InterDiffusion in Alloys and Semiconductors) for the DLR sounding rocket MAPHEUS. X-RISE recently became the umbrella for all our X-ray activities with the aim to make such a facility readily available for research aboard the ISS. Results are presented of recent XRR experiments on diffusion, solidification, and granular dynamics. The research carried out aboard parabolic flights in April 2013 and the sounding rocket MAPHEUS is discussed in comparison to extensive ground-based research. It is shown, that X-RISE now offers a frequent-flyer XRR-facility for parabolic flights and MAPHEUS. The following experiment inserts are currently available with the developer shown in brackets: i) compact X-ray transparent linear shear-cell for diffusion studies (DLR), isothermal furnace for studies of solidification (DLR), high-gradient furnace for solidification studies (Astrium), and a granular flow cell for studies of granular dynamics (DLR).

[C8.2] In-situ X-ray Diagnostics for Material Science Microgravity Experiments. Y. Houltz, P. Holm and C. Lockowandt. Swedish Space Corporation, P.O. Box 4207, SE-171 04 Solna, Sweden E-mail: ylva.houltz@ssc.se, phone: +46 8 627 62 00.

The development of compact micro-focus x-ray tubes and high-resolution digital x-ray sensors has made the utilization of real-time x-ray diagnostics on sounding rockets possible. These systems can offer image resolutions down to 5 µm at up to 6 frames per second for extended time periods. Swedish Space Corporation have during the last years developed a series of systems for in-situ X-ray radiography diagnostics for metallurgy experiments in order to study solidification phenomena, diffusion reactions, metal foaming, etc. in microgravity. These systems have successfully been adapted for both sounding rocket experiments and parabolic flight usage as well as for evaluation work in the laboratory. The following projects have been performed or are on-going: XRMON Metal foam experiment on sounding rocket MASER 11, 2008 and parabolic flights 2007, 2009: Images of aluminium metal foam generation and stabilization were recorded during the microgravity phase. Principal investigator was Dr. Francisco Garcia Moreno at Technical University Berlin.

XRMON Diffusion experiment on sounding rocket MAXUS 8, 2010: Three diffusion samples in three separate furnaces were studied simultaneously in the same x-ray image. The science team: Prof. A. Griesche, DLR Metallurgic Institute of Bonn, Germany, Prof. R. Mathiesen, Norwegian University of Science and Technology, Trondheim.
XRMON Gradient Solidification Experiment on MASER 12, 2012: The system performed real-time visualization of solidification in an Al-Cu alloy. A re-usable module framework “frequent flyer” was developed, including a Bridgman furnace for X-ray usage, enabling in-situ visualisation of directional solidification in microgravity. Principal investigator was Dr Henri Nguyen-Thi, University Paul Cézanne, France.

XRMON Isothermal Solidification Experiment on MASER 13, 2015: This experiment will re-use the framework of the XRMON-GF module, but also incorporate an isothermal furnace. Principal investigator is Dr David Browne, University College Dublin, Ireland.

XRMON Parabolic Flight Facility, June 2013: The same technology as used for the XRMON Gradient experiment, but adapted for parabolic flight environment, including an “easy to use” user interface and provisions for easy adaptations for future furnace developments.

XRMON Laboratory Set-up, Trondheim and Marseille 2012: An adaptation of the high resolution X-ray technology for laboratory usage.

The XRMON Microgravity Application Program is supported by the European Space Agency.


The Materials Science Research Rack (MSRR) is a research facility developed under a cooperative research agreement between NASA and ESA for materials science investigations on the International Space Station (ISS). MSRR was launched on STS-128 in August 2009 and currently resides in the U.S. Destiny Laboratory Module. Since that time, MSRR has logged more than 1000 hours of operating time.

The MSRR accommodates advanced investigations in the microgravity environment on the ISS for basic materials science research in areas such as solidification of metals and alloys. The purpose is to advance the scientific understanding of materials processing as affected by microgravity and to gain insight into the physical behavior of materials processing. MSRR allows for the study of a variety of materials, including metals, ceramics, semiconductor crystals, and glasses. Materials science research benefits from the microgravity environment of space, where the researcher can better isolate chemical and thermal properties of materials from the effects of gravity. With this knowledge, reliable predictions can be made about the conditions required on Earth to achieve improved materials.

MSRR is a highly automated facility with a modular design capable of supporting multiple types of investigations. The NASA-provided Rack Support Subsystem provides services (power, thermal control, vacuum access, and command and data handling) to the ESA-developed Materials Science Laboratory (MSL) that accommodates interchangeable Furnace Inserts (FI). Two ESA-developed FIs are presently available on the ISS: the Low Gradient Furnace (LGF) and the Solidification and Quenching Furnace (SQF). Sample Cartridge Assemblies (SCAs), each containing one or more material samples, are installed in the FI by the crew and can be processed at temperatures up to 1400°C.

ESA continues to develop samples with 14 planned for launch and processing in the near future. Additionally NASA has begun developing SCAs to support US PIs and their partners. The first of these Flight SCAs are being developed for investigations to support research in the areas of crystal growth and liquid phase sintering. Subsequent investigations are in various stages of development. US investigations will include a ground test program in order to distinguish the particular effects of the absence of gravity.
[C9.1] Transition of Thermocapillary-driven Convection in a High-aspect-ratio Liquid Bridge under Zero Gravity. H. Kawasaki¹, and I. Ueno²,³. ¹Division of Mechanical Engineering, School of Science & Technology, Tokyo University of Science, Noda, Chiba, Japan, ²Department of Mechanical Engineering, Faculty of Science & Technology, Tokyo University of Science, Noda, Chiba, Japan, ³Research Institute for Science & Technology (RIST), Tokyo University of Science, Noda, Chiba, Japan.

We focus on transitions of the convective fields of thermocapillary convections in a half-zone (HZ) liquid bridge of high aspect ratio by numerical approach. We have been inspired by the fluid physics experiments in a microgravity environment on a thermocapillary convection carried out on the Japanese Experiment Module ‘Kibo’ aboard the International Space Station since 2008. In these experiments, the thermocapillary-driven flow in a HZ liquid bridge of high Prandtl number (Pr) fluid in a range of the aspect ratio Γ (= height/radius) have been examined to firstly indicate the transition point of the flow field from the two-dimensional steady flow to the three-dimensional time-dependent ‘oscillatory’ one. These space experiments also indicate characteristics of the hydrothermal waves (HTW) after the transition as a function of the Γ, especially high Γ at which the ground experiments would be so hardly performed. The present research is intended to realize the flow fields in the high-Γ HZ liquid of rather high Prandtl number fluid, and make comparisons with the space experiments. In this numerical simulation, we carry out a series of simulation on the fluid of Pr = 28.6. Physical properties are decided by assuming 2-cSt silicone oil. The flow patterns before/after the onset of the transition as well as the transition points in the cases of Γ = 2.00, 2.50, 3.00 and 4.00 are focused.

In order to make comparisons with the results by the space experiments, we extract the spatio-temporal structures of the HTWs; especially the temperature variation over the free surface of the liquid bridge and its modal structure. Our transition points and the characteristics of the oscillatory flows are in good agreement with the results by the space experiments. It is noted that our simulation indicates there might exist an additional flow pattern between the transition point and the observed oscillatory flow in the space experiments in the case of Γ greater or equal to 2.5, and this additional flow pattern will bring a reasonable explanation to a unique correlation between the fundamental frequencies of the oscillatory flow and the flow patterns detected in the space experiments.

In the second part of work the linear stability of the unsteady motionless state is studied by solving the linearized equations. To determine the time for the onset of instability t*, the criterion proposed in [2] is used. The dependence of the value of t* defined according to the above criterion on the Grashof number is obtained. The comparison of t*(Gr) dependence with the results [1,2], and with the dependence obtained from the solution of the nonlinear problem is performed.

Supported by the Government of Perm Region (Contract number C-26/212).


[C9.2] Soret-Induced Instability of a Binary Mixture in Square Cavity Heated from Above. T.P. Lyubimova¹,², and N.A. Zubova ¹. ¹Institute of Continuous Media Mechanics, Perm, Russia; ²Perm State University, Perm, Russia.

The instability of incompressible viscous binary mixture with the Soret effect in square cavity heated from above is investigated. The no slip and zero mass flux conditions were imposed on the boundaries. It was assumed that horizontal boundaries are kept at constant different temperatures and vertical boundaries are adiabatic. The calculations were performed for water (90%)-isopropanol (10%) mixture. Initial conditions correspond to a uniform distribution of components and uniform temperature gradient directed upward. For liquid under consideration the separation parameter is negative therefore the Soret effect results in the increase of concentration of heavy component in the upper part of cavity and to the development of instability accompanied by sharp increase of the flow intensity and sharp decrease of concentration difference between the hot and cold walls.

The first part of work is devoted to the solution of nonlinear problem. Numerical data on temporal evolution of the flow characteristics and concentration fields for different values of Grashof number Gr are obtained. They reflect the onset of front instability and the development of fingers. We found that with the decrease of Gr the time for the onset of instability t* and the perturbation wavelength corresponding to the distance between the fingers increase. The comparison of the dependence t*(Gr) with the similar dependence obtained for the Soret-driven instability in a cubic cavity filled with the water-isopropanol mixture [1] is conducted.

In the second part of work the linear stability of the unsteady motionless state is studied by solving the linearized equations. To determine the time for the onset of instability t*, the criterion proposed in [2] is used. The dependence of the value of t* defined according to the above criterion on the Grashof number is obtained. The comparison of t*(Gr) dependence with the results [1,2], and with the dependence obtained from the solution of the nonlinear problem is performed.

Supported by the Government of Perm Region (Contract number C-26/212).


[C9.3] On oscillatory flow induced by thermocapillary effect in full-zone liquid bridge. Kosuke MOTEGI¹, Ichiro UENO²,³, Masaki KUDO⁴. ¹Division of Mechanical Engineering, School of Science & Technology, Tokyo University of Science, Noda, Chiba, Japan, ²Department of Mechanical Engineering, Faculty of Science & Technology, Tokyo University of Science, Noda, Chiba, Japan, ³Research Institute for Science & Technology (RIST), Tokyo University of Science, Noda, Chiba, Japan, ⁴Mechanical System Engineering Program, Tokyo Metropolitan College of Industrial Technology, Shinagawa, Tokyo.

Instabilities of thermocapillary convection in full-zone model of a high Prandtl number fluid under zero/normal gravity conditions is investigated by direct three-dimensional numerical simulation. Floating zone method is one of the producing methods of high-quality single crystal. There are two typical models in a floating zone method; one is the full-zone model simulated the full area of the floating zone method, and the other is the half-zone model simulated the half area of the floating zone. Full-zone model is confined between two coaxial cylindrical disks and heated at the mid height by an external ring heater. In the full-zone model the flow structure changes from two-dimensional steady to three-dimensional oscillatory flow by increasing the intensity of the thermocapillary effect. In a full zone method, the convective field of a floating zone method is obtained. A finite difference method on a non-homogeneous staggered grid is used for numerical simulation. The test fluids is 2cSt silicon oil (Pr=28). The liquid column is
warmed with assumed ambient gas temperature profile. In order to investigate the influence of the buoyancy we calculated both non-gravity condition and normal gravity condition. In consideration of the buoyancy, the vortex structure of the upper and lower part becomes asymmetry. To investigate the instability mechanism we perform energy budget analysis. The critical value of the full zone model is lower than that of the half-zone model by experience results. Axial Perturbation flow is large in full zone model. We found that the degrees of freedom at central portion are significantly related to the destabilization of the liquid column. Multi-mode structure is observed in a range of the aspect ratio by previous experimental works. By Fourier analysis, we investigated the spatial and temporal development of the mode. The power of the modes is changed in time. At normal gravity concision, the critical modes differ in the upper part and in the lower part by buoyancy. The higher order modes become more dangerous at the bottom of the liquid column.

[C9.4] Design Constraints Regarding the Use Of Fluids In Emergency Medical Systems For Space Flight. J. B. McQuillen. Fluid Physics and Transport Branch, NASA Glenn Research Center, Cleveland, OH, USA. The Exploration Medical Capability Project of the Human Research Program is tasked with identifying, investigating and addressing gaps existing in either knowledge or technology that need to be addressed in order to enable safer exploration missions. There are several gaps that involve treatment for emergency medical situations. Some of these treatments involve the handling of liquids in the spacecraft environment which involve gas-liquid mixtures handling, dissolution chemistry and thermal issues. Some of the recent technology efforts include the Intravenous fluid generation (IVGEN) experiment, the In-Suit Injection System (ISIS) experiment, and medical suction. Constraints include limited volume, shelf life, handling biohazards, availability of power, crew time and medical training.

Concurrent Session 10: Materials Science 3
Session Chair: Stefan Klein, German Aerospace Center (DLR)
Time: Tuesday, 8:00 am – 10:00 am

A strong gravitational field causes atomic displacement and sedimentation of atoms in solids, by which we can changes the crystalline state and composition in multi-component condensed matter, although a microgravity field has been used to suppress the effects of gravity. We presented a self-consistent diffusion equation for sedimentation of atoms in condensed matter. We have developed a high-temperature ultracentrifuge to generate a strong acceleration field of even over 1 million (1x10^6) G, and, for the first time, succeeded in realizing of the sedimentation of the constitutive solute atoms in a solid. The composition changes and reactions in various alloys, polymers, and some compounds have been investigated, and graded structure, chemical reaction have been realized. We also succeeded in realizing the sedimentation of isotope atoms and doping of impurity in semiconductors. In addition, recently we succeeded in realizing of structure changes in some oxides due to displacement of atoms, which enable us to synthesize of new materials by using strong gravity. It is expected that strong gravitational field will be used as an atomic-scale materials processing to control compositions, nanostructure, impurities and interface, and to synthesize new materials. In this talk, the basics of strong gravity science are reviewed, and recent progress and the future prospects for materials processing are described.

[C10.2] Evolution of the Shape of Detached GeSi Crystals in Microgravity. M. P. Volz and K. Mazuruk. NASA, Marshall Space Flight Center, Huntsville, AL, USA; University of Alabama in Huntsville, Huntsville, AL, USA.
A series of GeSi crystal growth experiments are planned to be conducted in the Low Gradient Furnace (LGF) onboard the International Space Station. An objective of these experiments is to understand the mechanisms of detached Bridgman growth, a process in which a gap exists between the growing semiconductor crystal and the crucible wall. Crystals grown without wall contact have superior quality to otherwise similar crystals grown in direct contact with a container, especially with respect to impurity incorporation, formation of dislocations, and residual stress in crystals. Numerical calculations are used to determine the conditions in which a gap can exist. According to crystal shape stability theory, only some of these gap widths will be dynamically stable. Beginning with a crystal diameter that differs from stable conditions, the transient crystal growth process is analyzed. In microgravity, dynamic stability depends only on capillary effects and is decoupled from heat transfer. Depending on the initial conditions and growth parameters, the crystal shape will evolve towards the crucible wall, towards a stable gap width, or towards the center of the crucible, collapsing the meniscus.

The authors gratefully acknowledge support from the NASA International Space Station Research Project.

[C10.3] Effect of Convection on Primary Dendrites: Observations from Ground-based and Space Station Processed Samples. Masoud Ghods, Mark Lauver, Surendra N. Tewari, Richard N. Grugel, Robert G. Erdmann, David R. Poirier. Department of Chemical and Biomedical Engineering, Cleveland State University, Cleveland, Ohio, USA, NASA-Marshall Space Flight Center, Huntsville, Alabama, USA, Department of Materials Science and Engineering, The University of Arizona, Tucson, Arizona, USA.
Influence of natural convection on primary dendrite array morphology during directional solidification is being investigated under the collaborative European Space Agency-NASA joint research program, “Microstructure Formation in Castings of Technical Alloys under Diffusive and Magnetically Controlled Convective Conditions (MICAST)”. Two Aluminum-7 wt pct Silicon alloy samples, MICAST6 and MICAST7, were directionally solidified in microgravity on the International Space Station at 18 K cm^-1 and 28 K cm^-2, respectively. Directional solidification involved a growth speed step increase (MICAST6-from 5 to 50 μm s\(^{-1}\)) and a speed decrease (MICAST7-from 20 to 10 μm s\(^{-1}\)). Primary dendrite arrays have been characterized in terms of primary dendrite spacing, dendrite trunk diameter and radial in-homogeneity. Primary dendrite spacing and the dendrite trunk diameters of space-grown samples follow closely the calculated predictions of dendritic growth in a diffusion-controlled field (i.e., no convection), whereas the same metrics in samples terrestrially solidified differ significantly from those grown in no...
convection. Thermosolutal convection in terrestrial samples produces extensive radial macrosegregation and dendrite clustering, generally not seen in the MICAST6 and MICAST7 samples. Samples grown under conditions with strong thermosolutal convection also show the greatest differences in the dendrite-metrics.

Supported by NNX08AN49G, NASA.

[C10.4] Homogeneous SiGe Crystal Growth Experiment in the International Space Station. Y. Arai1, K. Kinoshita1, T. Tsukada2, Y. Inatomi2, H. Miyata2, and R. Tanaka1. 1Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency, Sengen, Tsukuba, Ibaraki, Japan, 2Department of Chemical Engineering, Tohoku University, Sendai, Japan.

We report a brief summary of the homogeneous SiGe crystal growth experiment to clarify the two dimensional traveling liquidus zone (TLZ) theory which predicts the crystal growth interface shape and its composition. The TLZ method is a kind of the zone type crystal growth method. In this experiment, germanium with 20 mm length and 10 mm diameter will form a melt zone when heated above the melting temperature, which is set between a seed and a feed silicon single crystal. The microgravity condition offers the diffusion limited composition distribution in the SiGe solution zone which promises producing a homogeneous composition SiGe crystal and flattened crystal growth interface comparing with SiGe crystals grown on the ground by the TLZ method. In March, 2013, the first microgravity experiment was operated using a GHF (Gradient Heating Furnace) installed in the International Space Station. The SiGe crystal growth duration using the GHF was 123.8 hours. The maximum heater temperature and the heater translating speed were 1526 K and 0.10 mm/h, respectively. The maximum microgravity drag on the GHF rack during the experiment was less than 10^-4 G measured by an accelerometer. We aimed to produce the Si_{0.5}Ge_{0.5} crystal with 15 mm growth length on the central axis. The grown SiGe crystal length resulted in 17.2 mm and the averaged crystal growth velocity is calculated as 0.137 mm/h. The Ge mole fraction of the grown SiGe crystal is 0.485±0.015 on its central axis measured by an electron probe micro analyzer. This composition scattering corresponds to the soludis temperature variation of ±7.5 K. The one dimensional TLZ model allows calculation of the averaged temperature gradient in the zone. The calculated value ca. 9.5 K/cm in the microgravity experiment is larger than that obtained by the preliminary ground experiments using a GHF bread board model, 8 K/cm. The measured compositional profiles are utilized for improved heater temperature setting of the later SiGe crystal growth experiments to obtain more homogeneous SiGe crystals than that of the first experiment.

[C10.5] Particle Motion Due to Quenching of Lead-Tin Samples on ISS: Application to Coarsening in Solid-Liquid Mixtures. W. M. B. Duval1, R.W. Hawersaat1, P.W. Voorhees1. 1NASA Glenn Research Center, Cleveland, OH, USA; 2Northwestern University, Department of Materials Science and Engineering, Evanston, IL, USA.

Quenching of eutectic Lead-Tin samples with finite volume fractions of Tin particles occurs as a last step in coarsening or Ostwald ripening experiments to preserve the microstructure. Since the coarsening phase of the experiment occurs at nearly constant temperature, quenching introduces rapid cooling which disturbs the dynamical equilibrium phase. Hence, the transient effect of quenching on particle spatial distribution over a relatively short time interval of less than 10 sec, prior to solidification of the microstructure, is of interest. We address the effects of quenching on particle motion using a transient model that invokes non-equilibrium effects through the coupling of the conservation equations of mass, momentum (Navier-Stokes), energy and Lagrangian particle motion. We approximate the cooling boundary condition using a constant heat flux Neumann condition at the boundaries. The tracer particle assumption of the model is most applicable for the low volume fraction range of the experiments. The coupled set of incompressible Boussinesq equations are solved using finite-difference techniques. The results show that for tagged particles in the matrix, their trajectories over short time intervals are parabolic. The magnitude of the particle displacement under microgravity condition on ISS is on the order of 4x10^{-5} μm which is significantly less than the average particle radius in the range of 10 to 70 μm. This indicates that quenching on ISS will not affect particle spatial distribution measurements. However for ground-based condition, the particle displacement increases a million-fold on the order of 400 μm, this is less than 10 times the average large particle radius or 700 μm.

Supported by NASA NNX10AV36G.


Crystals of ZnSe and related ternary compounds, such as ZnSeS and ZnSeTe, will be grown by physical vapor transport in the Material Science Research Rack (MSRR) on International Space Station (ISS). The objective of the project is to determine the relative contributions of gravity-driven fluid flows to the compositional distribution, incorporation of impurities and defects, and deviation from stoichiometry observed in the crystals grown by vapor transport as results of buoyance-driven convection and growth interface fluctuations caused by irregular fluid-flows on Earth. The investigation consists of extensive ground-based experimental and theoretical research efforts and concurrent flight experimentation. The objectives of the ground-based studies are (1) to obtain the experimental data and conduct the analyses required to define the optimum growth parameters for the flight experiments, (2) to perform various characterization techniques to establish the standard procedure for material characterization, (3) to quantitatively establish the characteristics of the crystals grown on Earth as a basis for subsequent comparative evaluations of the crystals grown in a low-gravity environment and (4) to develop theoretical and analytical methods required for such evaluations. ZnSe and related ternary compounds have been grown by vapor transport technique with real time in-situ non-invasive monitoring techniques. The grown crystals have been characterized extensively by various techniques to correlate the grown crystal properties with the growth conditions.

The project is supported by NASA Life and Physical Sciences Division, Human Exploration and Operations Mission Directorate.
DECLIC is a multi-user facility to investigate critical fluids behaviour

G. Pont1, H. Burger1, S. Barde1, B. Zappoli1. 1Centre National d’Etudes Spatiales (CNES), Toulouse, France.

DECLIC is a multi-user facility to investigate fluids and transparent media, developed in the frame of a joint NASA/CNES research program. The instrument is a miniaturized thermo optical laboratory in which one can plug inserts containing the materials to be studied. Three inserts have been built so far. The ALI (Alice Like Insert) is dedicated to the study of SF6 as a near-ambient temperature critical fluid. The HTI (High Temperature Insert) is dedicated to the study of pure water as a critical fluid. The DSI (Directional Solidification Insert) is dedicated to the study of solidification of transparent alloys. The DECLIC facility was launched and installed in an Express Rack in 2009, and operated since then. It is monitored from the CADMOS control centre of CNES (France). The presentation will focus on the payload architecture and capabilities. We will show that DECLIC is a compact but versatile system, with outstanding performances, as demonstrated during the operations.

DECLIC operations and ground segment, an effective way to operate a payload.

H. Burger1, S. Barde1, Ph. Bioulez1, D. Blonde1, O. Belbis1, G. Pont1. 1Centre National d’Etudes Spatiales (CNES), Toulouse, France.

DECLIC is a multi-user facility to investigate critical fluids behaviour and directional solidification of transparent alloys. As part of a joint NASA/CNES research program, the payload has been successfully operated onboard the ISS since 2009. The operations and the ground segment have been prepared and developed so that the payload is operated in an effective way, by using most of the functions proposed by the NASA’s POIC (Payload Operations and Integration Center), but also by giving the scientists, through an internet connection, the capability to follow the operations in real-time. The presentation will give an overview on the ground segment architecture and on the operations organization. We will show how we have made the DECLIC operations effective and successful.

DECLIC: a look back at 4 years of operations.

G. Pont1, H. Burger1, S. Barde1, Ph. Bioulez2, D. Blonde3, 1Centre National d’Etudes Spatiales (CNES), Toulouse, France.

DECLIC is a multi-user facility to investigate critical fluids behavior and directional solidification of transparent alloys. As part of a joint NASA/CNES research program, the payload has been successfully operated onboard the ISS since 2009 with the three following inserts: The ALI (Alice Like Insert) is dedicated to the study of SF6 as a near-ambient temperature critical fluid. The HTI (High Temperature Insert) is dedicated to the study of pure water as a critical fluid. The DSI (Directional Solidification Insert) is dedicated to the study of the solidification of transparent alloys. The initial scientific program is over now and 2 out of the 3 inserts have already been returned in order to be refurbished. By the time of the congress, first sequences will have been performed with the first refurbished insert (HTI). During the presentation, we will look back at the four years of operations: some statistics and high level results will be presented, as well as some major anomalies were solved.

Optical Cells for Study of Near-critical Water Properties in Weightlessness using HTI-DECLIC On-board ISS.

C. Lecoutre-Chabot1, Y. Garrabos2, S. Marre3, D. Beyens3, U. Hegde4. 1CNRS, ICMCB, ESEME, UPR9048, F-33600 Pessac, France; 2Univ. Bordeaux, ICMCB, ESEME, UPR9048, F-33600 Pessac, France; 3PMMH/ESPCI & CNRS UMR 7636, Universités Paris 6 & Paris 7, 10 rue Vauquelin, 75005 Paris, France; 4Service des Basses Températures, CEA-Grenoble & Université Joseph Fourier, Grenoble, France; 5NASA Glenn Research Center (NASA-GRC), 21000 Brookpark Rd, Cleveland, OH 44135, USA; 6National Center for Space Exploration Research (NCSER), NASA GRC, Cleveland, OH 44135, USA.

We revisit optical cell designs dedicated to study the water properties near the liquid-gas critical point in the light of the flight results obtained using the high temperature insert (HTI) in the DECLIC-CNES instrument on board the International Space Station (ISS). First we emphasize the different diagnostics which can be used in the next experiments using the (water + salt) mixture solution in the refurbished HTI-R insert. Second, we show preliminary ground activities, at low temperature, in anticipation of future experimental research on the ISS to study reactive (water + organic compound) combustion related to the supercritical water oxidation process (SCWO).

This approach is based on three characteristic results of the past HTI flight experiments. The first concerns the turbidity measurements in the experimental cell at high temperature and high pressure. Indeed an optical method will be presented based on image analysis of the local turbidity gradients observed with HTI flight cell. The second point will focus on displacement of gas bubbles in relation with temperature gradient inside the fluid. The last point will study the unexpected gas-liquid phase distribution as a function of the critical temperature distance. A comparison between the different experiments using HTI, ALI (using SF6 fluid) and possibly HTI-R could be proposed.

Critical Phenomena Studies Utilizing the ISS DECLIC Facility: What’s Next?

Carole Lecoutre-Chabot1, Yves Garrabos2, Daniel Beyens3, Inseob Hahn4. 1ESEME-CNRS, Institut de Chimie de la Matière Condensée de Bordeaux, UPR9048 CNRS, Université Bordeaux I, France; 2ESEME-CEA, Laboratoire de Physique et Mécanique des Milieux Hétérogènes, UMR CNRS-ESPCI ParisTech, Université Paris 6-7, France; 4Jet Propulsion Laboratory, California Institute of Technology, CA, USA.

We propose a re-flight of the DECLIC Alice-Like-Insert (ALI-R) to measure light transmission and turbidity of sulfurhexafluoride (SF6) fluid in the single-phase region, closer to the critical density under microgravity conditions. The experiment will utilize the DECLIC facility on board ISS with a refurbished ALI’s fluid sample cell. The cell will be re-filled at the critical density. Together with the demonstrated temperature stability of the ALI insert, the new cell will allow studying the asymptotic behavior of the critical fluid approximately two orders of magnitude closer to the critical point. The ALI-R will measure experimentally the effects of the non-zero value of the Green-Fisher exponent in the liquid-gas critical point for sulfurhexafluoride (SF6) fluid.
the first time. We will present the status of the planned CNES/NASA ALI-R experiment and other potential critical phenomena studies utilizing the DECLIC facility in the future. Supported by NASA and CNES.

[C11.6] DECLIC: operations plan for the future. B. Zappoli¹, H. Burger¹, S. Barde¹, Ph. Bioulez¹, D. Blonde¹, G. Pont¹, ¹Centre National d'Etudes Spatiales (CNES), Toulouse, France.

DECLIC is a multi-user facility to investigate critical fluids behavior and directional solidification of transparent alloys. As part of a joint NASA/CNES research program, the payload has been successfully operated onboard the ISS since 2009 with the three following inserts: The ALI (Alice Like Insert) is dedicated to the study of SF6 as a near-ambient temperature critical fluid. The HTI (High Temperature Insert) is dedicated to the study of pure water as a critical fluid. The DSI (Directional Solidification Insert) is dedicated to the study of the solidification of transparent alloys. The initial scientific program is over now and 2 out of the 3 inserts have already been returned in order to be refurbished. The third one is planned to be returned by the end of 2013, again to be refurbished. So, the upcoming years will see refurbished inserts operations. The presentation will focus on the refurbishment process of the inserts and will introduce the operations plan for the refurbished inserts: operations until 2017 and maybe more are expected.
Concurrent Session 12: Fluid Physics 4
Session Chair: Issam Mudawar, Purdue University
Time: Tuesday, 10:30 am – 12:00 pm

[C12.1] Electrical Capacitance Volume Tomography for the Packed Bed Reactor ISS Flight Experiment. O.M. Marashdeh1, B.J. Motil1, and L.S. Fan1. 1Tech4Imaging LLC, Columbus, Ohio, USA; 2NASA Glenn Research Center, Cleveland, Ohio, USA; 3The Ohio State University, Columbus, Ohio, USA.

Fixed packed bed reactors are compact, require minimum power and maintenance to operate, and are highly reliable. These features make this technology a highly desirable unit operation for long duration life support systems in space. NASA is developing an ISS experiment to address this technology with particular focus on water reclamation and air revitalization. Earlier research and development efforts funded by NASA have resulted in two hydrodynamic models which require validation with appropriate instrumentation in an extended microgravity environment. To validate these models, the instantaneous distribution of the gas and liquid phases must be measured.

Electrical Capacitance Volume Tomography (ECVT) is a non-invasive imaging technology recently developed for multi-phase flow applications. It is based on distributing flexible capacitance plates on the peripheral of a flow column and collecting real-time measurements of inter-electrode capacitances. Capacitance measurements here are directly related to dielectric constant distribution, a physical property that is also related to material distribution in the imaging domain. Reconstruction algorithms are employed to map volume images of dielectric distribution in the imaging domain, which is in turn related to phase distribution. ECVT is suitable for imaging interacting materials of different dielectric constants, typical in multi-phase flow systems.

ECVT is being used extensively for measuring flow variables in various gas-liquid and gas-solid flow systems. Recent applications of ECVT include flows in risers and exit regions of circulating fluidized beds, gas-liquid and gas-solid bubble columns, trickle beds, and slurry bubble columns. ECVT is also used to validate flow models and CFD simulations. The technology is uniquely qualified for imaging phase concentrations in packed bed reactors for the ISS flight experiments as it exhibits favorable features of compact size, low profile sensors, high imaging speed, and flexibility to fit around columns of various shapes and sizes. ECVT is also safer than other commonly used imaging modalities as it operates in the range of low frequencies (~1 MHz) and does not radiate radioactive energy. In this effort, ECVT is being used to image flow parameters in a packed bed reactor for an ISS flight experiment.

[C12.2] Electro-Hydrodynamic Manipulation of Bubbles in Microgravity. Dana Qasem, Dr. Boris Khusid, Dr. Ezinwa Elele, Dr. Yueyang Shen, Dr. John Tang. Department of Chemical Engineering, New Jersey Institute of Technology, Newark, New Jersey.

The lack of the gravity-driven gas-liquid phase separation in microgravity has compromised a wide range of space technologies. The main idea behind the proposed electro-hydrodynamic (EHD) method for driving bubbles is to generate a local oscillatory fluid flow and a dielectrophoretic force by applying an alternating current field directly to a fluid via capacitive coupling to external electrodes. Contrary to the currently available direct current field-based microgravity techniques, the EHD method employs flow and field-induced forces to drive bubbles and suppresses electro-chemical reactions at the fluid-electrode interface. The parabolic flight tests were conducted in July 2013, aiming to validate the EHD method for the control and manipulation of bubbles in microgravity. These results will be presented at the conference. This work is supported by NASA grant NNX09AK06G.

[C12.3] Purdue and North Carolina Ag & Tech Undergraduate Student Space Station Experiment Program. Steven H. Collicott1 and John Kizito2, 1School of Aeronautics and Astronautics, Purdue University, West Lafayette, IN; 2Department of Mechanical Engineering, North Carolina Agricultural and Technical State University, Greensboro, NC.

Design of the hardware to produce the necessary capillary fluid physics in an up-mass experiment created by joint efforts of undergraduate teams at Purdue University and North Carolina Agricultural and Technical State University is described. Use of this science package to drive middle school STEM outreach is briefly described. Experiment operations, based on the highly successful astronaut operations of the Capillary Flow Experiments (CFE) in ISS, will deliver captivating observations and results which will serve as wonderfully visible inspirational tools for STEM students. The progression from ground-based research on water droplets obstructing lung passages to the highly functional but seemingly exotic test vessels is presented. The Surface Evolver code is applied to compute the static equilibrium topologies for small liquid volumes in specially designed test vessels. Results of the Surface Evolver computations are discussed, showing how the design being built enables the necessary science for a variety of ground and space based applications. Following science design details, the overall layout and construction of the experimental hardware is presented. Compromises faced in the design are discussed. Strengths of this smaller-budget space station experiment program are: the delivery of new, useful science results from a multi-institution undergraduate experiment in capillary fluid physics, a remarkably accessible science topic for undergraduates, K-12 science, and the public in general, and, chances of mission success maximized through the use of proven materials and design choices, data acquisition, and orbital operations learned from experiments previously and presently in ISS.

Supported by NASA grant NNX12AK93A, ISS National Lab Education Projects.

Concurrent Session 13: Materials Science 4
Session Chair: Ken F. Kelton, Washington University St. Louis
Time: Tuesday, 10:30 am – 12:00 pm

[C13.1] Fragility and Structural Ordering in Supercooled Liquids. K.F. Kelton1,2, J.C. Bendert1, M.E. Blodgett1, A.K. Gangopadhyay1,2. 1Department of Physics, 2Institute of Materials Science and Engineering, Washington University, St. Louis, MO 63130 USA.

Results from ground-based studies of liquid fragility, which support future ISS experiments, are presented. The best glass-forming liquids tend to be strong, with their structure assumed to change gradually from high temperature to near the glass transition temperature, Tg. In fragile liquids, little structural ordering occurs...
until the temperature approaches $T_g$. Frailty is typically measured from the temperature dependence of dynamical quantities such as the viscosity (kinetic fragility). The structural changes have not been measured directly, but are inferred from those kinetic data. Here, measurements of the liquid densities and shear viscosities as a function of time in Cu$_{100-x}$Zr$_x$ liquids demonstrate the presumed connection between structural change and kinetic fragility. An electrostatic levitation facility built at Washington University (WU-BESL) allowed measurements of containerlessly processed supercooled liquids in a high vacuum environment. The data show that at high temperatures the liquids that are strongest, based on the temperature dependence of the viscosity, also have the largest thermal expansion coefficients, signaling a greater rate of structural ordering. X-ray structure factors for many high temperature liquids, obtained from measurements at the Advanced Photon Source using WU-BESL, are also presented. These demonstrate that liquid fragility is linked with the rate of structural ordering. Theoretical studies have shown previously that liquid expansivity correlates with fragility near $T_g$; the results presented here show that at high temperatures they become anti-correlated. A crossover temperature is, therefore, predicted. Our studies of Vit 106 show evidence for this crossover, but they also cast doubt on a recent claim for a liquid-liquid phase transition in this liquid.

Supported by NASA NNX10AU19G and NSF DMR-12-06707.


In 2014, a series of experiments will be performed on various compositions using the Materials Science Laboratory (MSL) Electro-Magnetic Levitator (EML) in the International Space Station. Two important missions are the measurement of thermophysical properties and the investigation of convection influence on the solidification path. For both cases, understanding of convection in the melt is of critical importance. In the solidification research, it is hypothesized that the convection in melt affects the incubation time of nucleation of the stable phase in the metastable solid phase and the resulting microstructure. Meanwhile, a certain convection condition in the melt can jeopardize the validity of thermophysical data. For instance, when the viscosity is measured, the convection induced by electromagnetic forces in the melt must remain in a laminar regime. If turbulence exists, the excited melt will decay much faster due to turbulent eddy dissipation and one will obtain much larger viscosity values. Therefore, for the success of the missions, an ability to predict the convection in the melt as a function of test parameters such as heater and positioner voltages is mandatory. Using the validated magnetohydrodynamic model, the convection in the selected flight compositions has been predicted and characterized under various test conditions. The predicted convection data will allow the determination of the possible ranges of test parameters to accomplish the scientific goals.

Sponsored by NASA under grant NNX10AR71G.

[C13.3] Dendrite Growth Kinetics of D2 Tool Steel Undercooled Melts. J. Valloton$^{1,2}$, P. Delshad Khatibi$^3$, T. Volkmann$^1$, A. Maitre$^1$, D. Herlach$^1$, and H. Henein$^1$.

Advanced Materials and Processing Laboratory, University of Alberta, Edmonton, Canada; $^2$ Institut für Materialphysik im Weltraum, DLR, Cologne, Germany.

D2 tool steels are widely used in industry because of their good wear and abrasion properties due to their high volume fraction of carbides. The first solidifying phase is usually the iron-rich austenite, while other alloying elements such as carbon and chromium are rejected to the interdendritic liquid regions where eutectic carbides form. By reducing microsegregation and by evenly distributing carbides during solidification processing, the excellent mechanical properties of D2 tool steels can be further improved. Therefore, a rapid solidification technique is used on high-chromium high-carbon tool steels to refine the microstructure. In addition to the cooling rate, undercooling also has a significant effect on the microstructure during solidification of metals. However, systematic experimental work on the rapid solidification of D2 tool steels is still lacking.

Using electromagnetic levitation on D2 tool steels samples, undercoolings of the melt up to 200 K prior to solidification are achieved. First results show that the dendrite growth velocities measured as a function of undercooling are of the order of $\text{dm/s}$, i.e. one or two orders of magnitude lower than what is observed in simpler Fe-based peritectic systems, such as Fe-Co, Fe-Ni or Fe-Cr-Ni. This is imputed to the more complex solute redistribution in the multi-component D2 steel. For all undercoolings the microstructure of levitated samples consists of the stable austenite and (Fe, Cr)$_2$C$_3$ phases, as well as very small amounts of a yet undefined Mo-rich phase. Interestingly, the latter is not observed in D2 steel powders processed in drop tube experiments. Results of Earth-based experiments are compared with results obtained in microgravity during parabolic flights and are discussed in the frame of nucleation and growth models in undercooled melts.

The support of DLR, CSA FAST program, and ESA within the CCEMLCC project under contract # 4200020277 is gratefully acknowledged.

[C13.4] Growth Kinetics in Undercooled Fe-B Alloy Melts. C. Karrasch$^{1,2}$, T. Volkmann$^1$, and D. M. Herlach$^{1,2}$.

Institute of Materials Physics in Space, DLR, 51170 Cologne, Germany; $^1$ Institut für Experimentalphysik IV, Ruhr-Universität Bochum, 44780 Bochum, Germany.

The crystal growth in metallic alloys controls the evolution of the microstructure during solidification and therefore is of importance in material design. In the present work growth kinetics is measured as a function of undercooling. The results are analyzed within current theories of dendrite growth. For in-situ studies on deeply undercooled Fe-B melts electromagnetic levitation technique (EML) is used. The temperature is measured by an infrared-pyrometer while the solidification process is recorded by a high-speed video camera. Transformation of the undercooled liquid phase into the solid phase leads to a visible contrast due to the release of latent heat during rapid solidification. Undercoolings of more than 200 K prior to solidification are achieved, which leads to dendritic growth velocities of several m/s. The microstructure of the as-solidified sample is analyzed by SEM and EBSD. We investigate the effect of solute redistribution and trapping on the rapid growth of dilute Fe-1 at.% B alloy with B showing a small partitioning coefficient. If the B-
concentration is increased to Fe-5 at.% B the competition of ferrite and austenite phase can be studied. The phase selection depends on the undercooling of the melt. Concerning terrestrial EML the electromagnetic field necessary for levitation induces strong convective fluid flow inside the melt. The resulting fluid flow velocity (cm/s) is in the same order of magnitude as the dendrite growth velocity of Fe-10 at.% B samples. To investigate the effect of convection on the growth kinetics various experimental techniques are applied which provide different conditions of convection. Experiments in a quartz glass crucible without levitation are performed. The application of EML in reduced gravity during parabolic flight missions are carried out which provide a reduced level of forced convection compared with EML on earth. The ongoing investigations are precursor experiments of the ESA MAP project MAGNEPHAS where samples will be investigated aboard the ISS using the MSL-EMF facility.

This research work is supported by the German Research Foundation DFG within contract HE1601/18 and by the European Space Agency ESA under contract numbers 4200020277 and 4200014980.

**Concurrent Session 14: DECLIC (Session 2) – Near-Critical Fluids Phenomena**

**Session Chair:** Inseob Hahn, NASA Jet Propulsion Laboratory  
**Time:** Tuesday, 10:30 am – 12:00 pm

CNRS, ICMCB, ESEME, UPR9048, F-33600 Pessac, France,  
Univ. Bordeaux, ICMCB, ESEME, UPR9048, F-33600 Pessac, France,  
PMMH/ESPCI & CNRS UMR 7636, Universités Paris 6 & Paris 7,  
rue Vauquelin, 75005 Paris, France,  
Service des Basses Températures, CEA-Grenoble & Université Joseph Fourier, Grenoble, France,  
Jet Propulsion Laboratory, California Institute of Technology, CA91109, USA.

Key mechanisms of the boiling phenomena in the two-phase region of SF6 close to its critical point (CP) are observed using the high-quality thermal and optical environment of the CNES facility ALI-DECLIC on board the International Space Station (ISS). Indeed, the weightlessness environment is an irreplaceable powerful tool for boiling studies such that it eliminates buoyancy forces and favors the three-dimensional spherical shape of the gas bubble. The ALI-DECLIC experiments have benefited from: i) the well-adapted design of the test cells, ii) the remote operation capability of the DECLIC instrument required for long-duration experiments in stable thermal and microgravity environment, iii) the repeatability of the controlled thermal disturbances, and iv) the vanishing of the critical heat flux value at the critical point enabling the boiling crisis studies without applying large heat load. The boiling phenomena were observed by light transmission or interferometry when the cells filled with pure SF6 at a near-critical density are driven away from equilibrium. Specially designed heaters are implemented directly inside the bulk fluid or near the boundary of the sapphire optical window of the cell. The experiments were performed in the 10K temperature range below the critical temperature \( T_c \), with special attention between 0.1mK<T-T_c<3mK. The main originality of this investigation is then provided by monitoring the boiling phenomena at low heat flux ranges without complications due to the typical temperature gradients. This is uniquely achieved by the fine control of the liquid-vapor properties by tuning the distance to the CP, and by taking advantage of the universality of critical phenomena and the so-called “critical slowing down” effect near the CP. We show the key observations of the gas bubble spread over the heating surface which permits to characterize the regime where vapor bubbles nucleate separately and grow. We also point out the dynamics of the liquid dryout (i.e. the formation of the vapor film on the heater), and the triple contact line motion. These phenomena are at the origin of the boiling crisis where the mentioned vapor film reduces drastically the heat transfer at the heater wall.

U. Hegde, and M. C. Hicks.  
National Center for Space Exploration Research, NASA John H. Glenn Research Center, Cleveland, OH, USA.

The effects of gravity on the fluid mechanics of supercritical water jets are being studied at NASA to develop a better understanding of flow behavior for purposes of advancing supercritical water oxidation (SCWO) technologies for applications in reduced gravity environments. These studies provide guidance for the development of future SCWO experiments in new experimental platforms that will extend the current operational range of the DECLIC (Device for the Study of Critical Liquids and Crystallization) Facility on board the International Space Station (ISS). The hydrodynamics of supercritical fluid jets is one of the basic unit processes of a SCWO reactor. These hydrodynamics are often complicated by significant changes in the thermo-physical properties that govern flow behavior (e.g., viscosity, thermal conductivity, specific heat, compressibility, etc), particularly when fluids transition from sub-critical to supercritical conditions. Experiments were conducted in a 85 ml reactor cell under constant pressure with water injections at various flow rates. Flow configurations included supercritical jets injected into either sub-critical or supercritical water. Profound gravitational influences were observed, particularly in the transition to turbulence, for the flow conditions under study. These results will be presented and the parameters of the flow that control jet behavior will be examined and discussed.

U. Hegde was supported under NASA Contract NNC08BA08B with the National Center for Space Exploration Research.

[C14.3] Ising-like Equation-of-state Models in the Light of DECLIC-ALI Turbidity Measurements in Off-critical SF6 On-board ISS.  
CNRS, ICMCB, ESEME, UPR9048, F-33600 Pessac, France,  
Univ. Bordeaux, ICMCB, ESEME, UPR9048, F-33600 Pessac, France,  
PMMH/ESPCI & CNRS UMR 7636, Universités Paris 6 & Paris 7,  
rue Vauquelin, 75005 Paris, France,  
Service des Basses Températures, CEA-Grenoble & Université Joseph Fourier, Grenoble, France,  
Jet Propulsion Laboratory, California Institute of Technology, CA91109, USA.

Two different classical-to-critical crossover formulations of the universal equation-of-state of Ising-like systems are tested analyzing new light transmission and turbidity measurements in microgravity environment. These data were obtained in the homogeneous region of SF6 close to
its critical point, in the high-quality thermal and optical environment of the CNES dedicated facility ALI-DECLIC on board the ISS. These precise measurements have benefited from the well-defined off-density criticality of the test cell and from the microgravity environment of the space station. The asymptotic formulations for the static isothermal compressibility, the correlation length, and then the turbidity are verified. The theoretical functional forms of the turbidity discriminate the determination of two asymptotic, fluid-dependent, Ising-like scale factors from the single crossover parameter when experimental data are covering a region of the near-critical phase surface unattainable from ground-based experiments. The results confirm that the Ising-like critical behavior, in the pressure-temperature-density phase surface close to the SF6 critical point, can be described in conformity with the universal features estimated by the renormalization-group methods.

[C14.4] Supercritical Water Mixture (SCWM) Experiment in the High Temperature Insert-Reflight (HTI-R). Michael Hicks1, Uday Hegde2, Yves Garrabos3, Carole Lecoutre3, Gabriel Pont4, Bernard Zappoli4. 1NASA Glenn Research Center (NASA-GRC), 2National Center for Space Exploration Research (NCSER), 3Institute of Condensed Matter Chemistry of Bordeaux (ICMCB), Bordeaux, France, 4National Centre for Space Studies (CNES), Toulouse, France. Current research on supercritical water processes on board the International Space Station (ISS) focuses on salt precipitation and transport in a test cell designed for supercritical water. This study, known as the Supercritical Water Mixture Experiment (SCWM) serves as a precursor experiment for developing a better understanding of inorganic salt precipitation and transport during supercritical water oxidation (SCWO) processes for the eventual application of this technology for waste management and resource reclamation in microgravity conditions. During typical SCWO reactions most inorganic salts present in the reactant stream will precipitate and begin to coat reactor surfaces and control mechanisms (e.g., valves) often severely impacting the system’s performance. The SCWM experiment employs a Sample Cell Unit (SCU) filled with an aqueous solution of Na₂SO₄ 0.5% -w at the critical density and uses a refurbished High Temperature Insert (HTI), which was used in an earlier ISS experiment designed to study pure water at near-critical conditions. The insert, designated as the HTI-Reflight (HTI-R) will be deployed in the DECLIC (Device for the Study of Critical Liquids and Crystallization) Facility on the ISS. Objectives of the study include measurement of the shift in critical temperature due to the presence of the inorganic salt, assessment of the predominant mode of precipitation (i.e., heterogeneously on SCU surfaces or homogeneously in the bulk fluid), determination of the salt morphology including size and shapes of particulate clusters, and the determination of the dominant mode of transport of salt particles in the presence of an imposed temperature gradient. Initial results from the ISS experiments will be presented and compared to findings from laboratory experiments on the ground. Supported by the Life and Physical Sciences Division of the NASA Human Exploration and Operations Mission Directorate, HEOMD.
Concurrent Session 15: Enabling Technology 1
Session Chair: Sidney Sun, NASA Ames Research Center
Time: Tuesday, 2:00 pm – 3:30 pm


The ISS provides researchers with a unique environment for conducting rodent research. This unique environment also presents some new challenges that must be considered in designing experiments using the new Rodent Research suite of hardware. Operational considerations for Rodent Research experiments, including the limitations in crew time available, are important considerations for researchers submitting research proposals on future Rodent Research flights.

Rodent Research is crew-time-intensive and researchers proposing flight research will need to consider resource limitations in designing experiment protocols. All animal manipulations (injections, dissections, etc.) will occur inside a glovebox in order to provide the levels of containment required to ensure crew safety when working with animals and toxic chemicals. Crew time is limited to no more than 6.5 hours per day divided into sessions of no more than 3 hours. Depending on the complexity of the operations, planning for 3 to 5 animals per day for operations such as dissections and densitometry scans is a good guideline for designing experiment protocols.

For experiments requiring more than approximately a 21-day microgravity exposure researchers should plan on long-term storage of their preserved specimens for periods ranging from 3 to 6 months. Preservation methods available include freezing or chemical fixation at either ambient or refrigerated temperatures. Live animal return is not currently available and will be constrained by limited space on board the recovery ship for science operations or receipt of animals at the dock 48 hours post-splashdown off the coast of Southern California.

The first Rodent Research flights are manifest for launch on SpX-4 (Spring/Summer 2014) and SpX-6 (Winter 2014/2015). The first flight, Rodent Research-1, will validate the hardware and operations (dissections and tissue preservation) needed to enable future science. Rodent Research-2, will be the first science flight and will expand the on-orbit capabilities to include experiment durations up to 60 days, bone densitometry, and anesthesia. At least one Rodent Research flight per year on the ISS is being planned and interested researchers should submit proposals in response to NASA Research Announcements.

Supported by the International Space Station Program Office (JSC) and Space Life and Physical Sciences Division (NASA HQ).


In 1975, a malfunction aboard the spacecraft used in the Apollo Soyuz Test Project caused toxic gas to leak into the spacecraft, stopping the heart of pilot Vance Brand. The crew was able to use traditional CPR methods to resuscitate the pilot because they were in normal Earth gravity. However, as commercial space travel becomes more prevalent, the probability of cardiovascular incidents in microgravity will increase. To prevent a tragedy, it is important to improve the efficiency and effectiveness of cardiovascular related equipment in this new environment. The current NASA CPR procedure requires 3 to 4 minutes of preparation, two rescuers, and a large rigid surface that the patient can be strapped to. This can potentially be reduced to 90 seconds of preparation, one rescuer, and a small, free-floating strap system using our active compression decompression cardiopulmonary resuscitation (ACD-CPR) method. In addition to the compressions of regular CPR, our procedure actively decompresses the chest using a suction device. This device has been shown to improve coronary artery pressure by 30% over traditional CPR.

To begin the procedure, the rescuer attaches himself/herself behind the patient with a strap restraint, places the device on the victim’s sternum, and then performs ACD-CPR. Effective CPR requires at least 100 compressions per minute at a depth of compression of 2 inches. The compressions simulate the heart beating which drives 5000 mL/min of blood through the body and heart. The team is testing to determine whether the necessary depth and rate of compressions can be achieved using our method. In space our method would be preferred to traditional methods because it requires smaller equipment, is more versatile, and decreases rescue time. Our procedure was tested aboard NASA’s ‘Weightless Wonder” microgravity aircraft both in June 2012 and in June 2013. The preliminary results show it is possible to achieve the rate and depth of compressions necessary for effective resuscitation with our procedure.

Our thanks to Advanced Circulatory Systems, Missouri University of Science and Technology, and Phelps Regional County Medical Center.


NASA is building the Bioculture System, which is the next generation incubator for cell biology and microbiology research on ISS to meet the space flight research priorities of the 2010 Space Biosciences Roadmap and the 2011 Decadal Report. The Bioculture System supports culturing a diversity of cell culture types and microbiological specimens for up to sixty days. It is comprised of a docking station that carries ten independent incubation units, or “Cassettes”. Each individual Cassette contains a cooling chamber (+5 °C) for temperature sensitive solutions and samples or long duration fluids and sample storage and an incubation chamber (ambient to +42 °C). The cooling chamber can accommodate one 200 ml media bag and sixteen smaller fluid/sample bags. The only shared component is the gas supply. Each Cassette houses an independent fluidics system comprised of a biochamber, medical-grade fluid tubing, medium warming module, oxygenation module, fluid pump, and sixteen solenoid valves for automated biochamber injections or sampling. The Bioculture System provides the user with the ability to select the incubation temperature, fluid flow rate,
and automated biochamber sampling or injection events for each separate cassette. Furthermore, the Crew can access the biochamber, media bag, and accessory bags on-orbit using the Microgravity Science Glovebox. The Bioculture System permits initiation of cultures, subculturing, injection of compounds, and removal of samples for on-orbit processing using ISS facilities such as the WetLab-2 qPCR system. Also, the media and sample bags may be changed out, which allows for extending experiments beyond sixty days. The Bioculture System provides data telemetry and commanding from the ground. The first flight of the Bioculture System will occur during ISS Increment 39/40, currently scheduled for August 2014. During this flight the Bioculture System performance and functions to support biological experiments will be tested and validated. Eight of the Cassettes will carry cell cultures (human cardiomyocytes or adipose tissue derived stem cells), and two of the Cassettes will be dedicated purely to engineering characterization. The crew will validate two manual procedures: accessing biospecimens and change out of the gas supply. At the end of the validation flight a report will be published.


The primary objective of NASA Ames Research Center’s WetLab-2 Project is to place on the ISS a research platform to facilitate gene expression analysis via quantitative real-time PCR (qRT-PCR) of biological specimens sampled or cultured on orbit. The WetLab-2 equipment will be capable of processing multiple sample types ranging from microbial cultures to animal tissues dissected on-orbit. In addition to the logistical benefits of in-situ sample processing and analysis, conducting qRT-PCR on-orbit eliminates the confounding effects on gene expression of reentry stresses and shock acting on live cells and organisms. The system can also validate terrestrial analyses of samples returned from ISS by providing quantitative on-orbit gene expression benchmarking prior to sample return. The ability to get on orbit data will provide investigators with the opportunity to adjust experimental parameters for subsequent trials based on the real-time data analysis without need for sample return and re-flight. Finally, WetLab-2 can be used for analysis of air, surface, water, and clinical samples to monitor environmental contaminants and crew health. The verification flight of the instrument is scheduled to launch on SpaceX-5 in Aug. 2014.

Progress to date: The WetLab-2 project completed a thorough study of commercially available qRT-PCR systems and performed a downselect based on both scientific and engineering requirements. The selected instrument, the Cepheid SmartCycler®, has advantages including modular design (16 independent PCR modules), low power consumption, rapid ramp times and the ability to multiplex and assay up to four genes of interest in each module. The WetLab-2 team is currently working with Cepheid to modify the unit for housing within an EXPRESS rack locker on the ISS. This will enable the downlink of data to the ground and provide uplink capabilities for programming, commanding, monitoring, and instrument maintenance. The project is currently designing a module that will lyse the cells and extract RNA of sufficient quality for use in qRT-PCR reactions while using a housekeeping gene to normalize RNA concentration and integrity. Current testing focuses on two promising commercial products and chemistries that allow for RNA extraction with minimal complexity and crew time.

The WetLab-2 Project is supported by NASA’s ISS Program at JSC, Code OZ.

[C15.5] Current Trends in High Throughput Methods for In-Situ Space Research. Fathi Karouia1,2, Kia Peyvan3, Orlando Santos1, and Andrew Pohorille1,2. 1NASA Ames Research Center; 2University of California San Francisco; and 3Peyvan Systems.

Over the last two decades high throughput methods have revolutionized the field of biology. The key components of this new approach are genomics, proteomics and metabolomics, collectively known as “omics”. They are aimed at studying content and activity of the full complement of genes, proteins and metabolites, respectively, in an organism or a consortium of organisms. Even though “omics’ approaches are relatively new, they are already widely used and have yielded many important insights to biology and medicine. In the half-century of space exploration multiple lines of evidence have accumulated to state with near-certainty that effects of space environments are not limited to a single gene or even a small number of genes, or a single subcellular component, but instead influence many genes and cell functions. This implies that they should be studied using global, integrative methods. This, in turn, means, that “omics” approaches are not only helpful, but are indispensible for space biology. To achieve the expected advances from “omics” technologies, the current paradigm of performing data analyses post-flight should change to include “omics” tools for in situ research. However, developing “omics” instruments for space applications remains a challenge even in the case of mature methods. Among contributing factors are the need for substantial miniaturization and automation, compatibility of all protocols and materials with conditions in space, safety issues and the requirements for low power and operation independent of the direction of the gravity vector. We will discuss which “omics” technologies are currently amenable to adaptations for space applications and how these adaptations can be achieved. We will review ongoing efforts aimed in this direction and discuss scientific benefits that they might bring. In this context, we will argue that, with sufficient commitment, at least some instruments for high-throughput measurements could be ready for deployment on-board spacecraft in the next 2-3 years. Once developed and deployed, “omics” tools can be used for a wide variety of high-value studies on biological systems ranging from microorganisms to humans that hold significant potential for discoveries in space biology, biotechnology, pharmacology and medicine.

Supported by the NASA Astrobiology Science and Technology Instrument Development and Exobiology Programs.

[C15.6] Gene Expression Measurement Module (GEMM): the door to high-throughput in-situ analyses of biological systems in space. Andrew Pohorille1,2, Kia Peyvan3, Fathi Karouia1,2, and Antonio Ricco1,4. 1NASA Ames Research Center; 2University of California San Francisco; 3Peyvan Systems; and 4Stanford University.

A central, long-standing goal of the astrobiology program that holds promise for both major scientific discoveries and exciting the
general public is to understand life in outer space and on other celestial bodies. One strategy towards achieving this goal is to determine the potential for terrestrial microbial life to adapt and evolve in space environments. Identifying the limits of terrestrial life in space and the accompanying molecular adaptations is a prerequisite for developing predictions and hypotheses about life on other worlds. The ability of microorganisms to survive in a wide range of conditions encountered in space would support the hypothesis that terrestrial life might not be a local planetary phenomenon, but instead could expand its evolutionary trajectory beyond its planet of origin. This would, in turn, support the notion that terrestrial life may not be unique and similar life forms might exist elsewhere in the Universe.

In order to facilitate studies on the impact of the space environment on biological systems, we have developed GEMM (Gene Expression Measurement Module) - an automated, miniaturized, integrated fluidic system for in-situ measurements of gene expressions in bacterial samples. The project has been funded through the ASTID program. The GEMM instrument is capable of (1) lysing bacterial cell walls, (2) extracting and purifying RNA released from cells, (3) hybridizing it to probes attached to a microarray and (4) providing electrochemical readout, all in a microfluidics cartridge. Its first application on a nanosatellite platform is to cultivate and measure gene expression of the photosynthetic bacterium Synechococcus elongatus, a cyanobacterium known for its metabolic diversity and resilience to adverse conditions, under light and dark cycles exposed to polar orbit for a period of 6 months. The integration and end-to-end technology validation of this instrument will be discussed. In particular, results demonstrating that the instrument properly measures gene expression after cellular lysis, nucleic acid extraction, its purification, and hybridization to an electrochemical array will be presented and compared to commercial microarray analysis. Finally, a proposed version of GEMM that is capable of handling both microbial and tissue samples on the International Space Station will be briefly reviewed.

Supported by the NASA Astrobiology Science and Technology Instrument Development and Exobiology Programs.

Concurrent Session 16: Plants 1
Session Chair: Robert Ferl, University of Florida
Time: Tuesday, 2:00 pm – 3:30 pm

[C16.1] Transcriptome Analyses of Arabidopsis thaliana Seedlings Grown in Space: Implications for Gravity-Responsive Genes. Melanie J. Correll\textsuperscript{1}, Tyler P. Pyle\textsuperscript{2}, Katherine D.L. Millar\textsuperscript{2}, Yijun Sun\textsuperscript{3,4}, Jin Yao\textsuperscript{5}, Richard E. Edelmann\textsuperscript{6}, John Z. Kiss\textsuperscript{2}. 1 Agricultural and Biological Engineering Department, University of Florida, Gainesville, FL, USA; 2Department of Biology, University of Mississippi, University, MS, USA; 3Department of Microbiology and Immunology, New York State Center of Excellence in Bioinformatics and Life Sciences, The State University of New York, Buffalo, NY, USA; 4Electrical and Computer Engineering Department, University of Florida, Gainesville, FL, USA; 5Department of Botany, Miami University, Oxford, OH, USA.

The transcriptome of seedlings were analyzed from experiments performed on the International Space Station (ISS) to study the interacting effects of light and gravity on plant tropisms (project named TROPI-2; Kiss et al. 2012). Seeds of Arabidopsis were germinated in space, and seedlings were then grown in the European Modular Cultivation System (EMCS) for 4 days at \( \sim \)1g followed by exposure to a range of gravitational accelerations (from microgravity to 1g) and two light treatments (blue light with or without a 1 h pretreatment with red). At the end of the experiments, the cassettes containing the seedlings were frozen in the Minus Eighty Laboratory Freezer (MELFI) and returned to Earth on space shuttle mission STS-131. The RNA was extracted from whole seedlings and used for the transcriptome analyses. A comparison of 1g-spaceflight samples with 1g-ground controls identified 230 genes that were differentially regulated at least two fold, emphasizing the need for “in situ” tissue fixation on a 1g centrifuge as an important control for spaceflight experiments. A further comparison of all spaceflight samples with ground controls identified approximately 280 genes that were differentially regulated at least two fold. Of these genes, several were involved in regulating cell polarity (i.e., auxin, calcium, lipid metabolism), cell wall development, oxygen status, and cell defense or stress. However, when the transcriptome of the all g-treated spaceflight samples were compared with microgravity samples, only \( \sim \)130 genes were identified as being differently regulated (\( \text{P} \leq 0.01 \)). Of this subset, only 27 genes were at least two-fold differently regulated between microgravity and 1g space samples and included putative/pseudo/undefined genes (14), transposable elements (5), an expansin (ATEXP24; At1g21240), a cell-wall kinase (WAK3; At1g21240), a laccase-like flavonoid oxidase (T710; At3g48100), among others.

Supported by the National Aeronautics and Space Administration (NNX10AF44G).

[C16.2] BRIC 17: Capturing Plant Ca\textsuperscript{2+} and Hypoxic Signaling Networks Aboard the ISS. Won-Gyu Choi, Sarah Swanson, Simon Gilroy. Department of Botany, University of Wisconsin, Birge Hall, 430 Lincoln Drive, Madison, WI 53706, USA.

This research has capitalized on a rapid turn-around space flight opportunity and the BRIC-PDFU hardware to address how spaceflight affects gene expression related to low oxygen response (hypoxia/anoxia) in Arabidopsis. Root zone hypoxia is thought develop in spaceflight as weightlessness leads to a reduction in the buoyancy-driven convection that usually aids in gas exchange around organisms. This in turn leads to the development of oxygen-limiting conditions with adverse effects on plant vigor and yields. Our analysis of Ca\textsuperscript{2+} signaling responses and associated gene expression patterns in Arabidopsis indicates Ca\textsuperscript{2+} signaling is linked to anoxic response in plants. We identified a suite of Ca\textsuperscript{2+}-dependent proteins that show rapid transcriptional responses to anoxia in both roots and shoots and mutants in two such genes, aca1-2 and cax2-2 (both Ca\textsuperscript{2+} transporters) are resistant to anoxic challenge on Earth. These mutants are also disrupted in gravitropic response, suggesting that Ca\textsuperscript{2+} signaling may provide a point of cross-talk between these anoxic and gravity response systems. We therefore flew wild type and two alleles of CAX2 to the ISS on SpaceX-CRS2 in March 20013 as part of the BRIC 17 experimental package. The plants were germinated and grown on board the ISS for 8 days, fixed in RNAlater, frozen in the MELFI and returned frozen for subsequent analysis of growth and transcriptional profile versus parallel ground-based controls. Initial qPCR based profiling of target stress-related genes...
An Extraterrestrial Approach to Gene Discovery. Natasha J. Sng1, Anna-Lisa Paul1,2, and Robert J. Ferl1,3. 1Program in Plant Molecular and Cellular Biology; 2Horticultural Science Department; 3Interdisciplinary Center for Biotechnology Research, University of Florida, Gainesville, Florida, USA.

Plants are sessile organisms that have evolved many different mechanisms to aid in their ability to respond and adapt quickly to changes in their environment. Sending plants into orbit provides a unique opportunity to observe how plants adjust to the novel environmental features of spaceflight, such as the lack of gravity. In a recent study, we found that Arabidopsis thaliana (Arabidopsis) responded to spaceflight with organ-specific differential expression of hundreds of genes as compared with ground controls - leaves, hypocotyls, and roots each displayed unique patterns of response. Arabidopsis is a model plant that has been fully sequenced and well characterized on many levels. Yet, there are numerous genes present in the Arabidopsis genome that encode proteins of unknown function. Over 100 of these unknowns are among the genes that are differentially expressed by at least 2-fold in response to spaceflight in an organ specific manner. Many of the unknowns have interesting and complex patterns of expression; several are highly induced or repressed in one plant organ, while being virtually unchanged in the others organs, whereas some of these genes are induced or repressed in two or across all organs. The spaceflight environment could thus provide unique clues to the possible role of these genes of unknown function in gravity sensing or in some of the other categories highly represented in the spaceflight transcriptome, which includes cell wall remodeling, auxin signaling and plant developmental processes. For instance, we identified a gene (Mutant 63) that showed significant upregulation in roots by 12 fold change in spaceflight. Knock-out mutant 63 grown on vertical plates appeared similar to the Col-0 wild-type ecotype. However, growing Mutant 63 on a 45 degree slanted plate, altering the plant’s perceived gravity condition, resulted in these plants having a reduced biomass phenotype. By generating a variety of transgenic plants to genes identified by spaceflight, and exposing them to altered gravity conditions such as slanted plates or clinorotation, we intend to elucidate unknown gene functions.

This work was supported by NASA grants NNX09AL96G, NNX07AH270 and NNX12AM69G to RJF and A-L Paul.

Long Term Exposure to Microgravity Triggers the Transcriptional Reprogramming of Cell Wall-related Genes in Arabidopsis. Taegun Kwon, J. Alan Sparks, Jin Nakashima, Stacy Allen, Yuhong Tang, Elison Blancaflor. Samuel Roberts Noble Foundation, Ardmore, OK, USA.

Plants have evolved under the constant gravity on Earth. Gravity is one of the major stimuli that influence plant structure and development. The hardware of the Biological Research in Canisters (BRIC 16) on board the Space Shuttle Discovery mission STS-131 offered us an opportunity to investigate how plants respond to microgravity. We used microarray to obtain the whole genomic transcription profiles from Arabidopsis seedlings grown in space and on ground for 13 days in dark. For our microarray analysis, we applied a stringent filter (> 4 fold change and False Discovery Rate 0.1%) resulting 117 down-regulated and 27 up-regulated genes in space. Quantitative RT-PCR confirmed the microarray results for down-regulated genes. However, many of the up-regulated genes in the microarray dataset were not confirmed by qRT-PCR. The down-regulated genes were highly enriched in genes encoding peroxidases, glycosylhydrolases and heme binding activities predicted to function in the extracellular matrix or cell wall. The altered expression of cell-wall-related genes may account for structural abnormalities that were observed in the cell wall of our space samples under the transmission electron microscope. Several of the genes that were down-regulated are also known to function in proper development of roots and root hairs. A subset of the microgravity-repressed genes was co-regulated under mutant background deficient in genes encoding well-characterized root hair transcription factors. Our data indicate that these transcription factors not only control root hair development but might also regulate the cell-wall-related gene expression in response to microgravity.

This work was supported by NASA grants NNX10AF43G and NNX12AM94G.

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This work was supported by NASA grants NNX10AF43G and NNX12AM94G.
addition, a ground control was carried out under conditions that mimicked the temperature and CO₂ levels observed in the flight experiment. Protocols have been optimized for sample harvesting and RNA isolation from limited quantities of tissue. Gene expression profiles of WT and InsP₅-pase roots at 1g and micro-g will be compared by RNA-Seq analysis. It is anticipated that this study will lead to the identification of the molecular changes specifically mediated by InsP₅ in the space environment. Supported by NASA grant # NNX10AM72G.

[C16.6] Differential Gene Expression in Jatropha curcas In Vitro Cultures Exposed to Microgravity. W.A. Vendrame¹ and A. Pinares¹.

¹ Environmental Horticulture Department – IFAS – University of Florida, Tropical Research and Education Center, Homestead, FL, USA.

Jatropha (Jatropha curcas L.) has been identified as a suitable species for biofuel production. However, the species is undomesticated and breeding and genetic improvement programs are necessary. Microgravity offers a unique environment for assessment of genetic variation that can be used in genetic improvement programs. The objective of this study was to evaluate the differential gene expression of in vitro jatropha cultures exposed to microgravity. In vitro cultures of two jatropha accessions (Brazil, India) were initiated from cotyledon (CO), leaf (L) and stem (ST) sections. Different RNA isolation protocols were evaluated to assure sufficient RNA of good quality for subsequent microarray analysis. Groups of 10 petri dishes containing treatments (accession x explant tissue) were arranged in Group Activation Pack flight hardware (petriGAPs), previously validated for spaceflight experiments, and exposed to microgravity for periods varying from 14 to 125 days under different space shuttle missions (STS-133 and STS-135). Once returned, cultures were processed for RNA isolation and subsequent microarray analysis. Comparisons were performed between ground and orbit samples for effects of medium and microgravity exposure time. The type of tissue influenced the efficiency of the RNA isolation and the Plant Reagent and Trizol protocols returned the best RNA quality and quantity.

Microarray analysis revealed differential patterns of gene expression between ground and orbit samples and expression patterns were affected by accession and explant tissue. For all comparisons performed, between 9 and 522 genes were differentially expressed. Over 20% of those genes were expressed at higher levels by over 2-fold. Higher levels of differential gene expression were observed in orbit. Gene expression was also affected by exposure time to microgravity, with periods of 111 days showing higher expression levels. Specific groups of genes showing differential gene expression were grouped using a cluster analysis. The roles of different gene groups and the observed genetic changes are discussed for their potential impact on new cultivar development. Differential gene expression induced by microgravity may assist in future genetic improvement programs.

Acknowledgments: The authors thank Vecenergy, the Vecello Group for the financial support provided for this study, BioServe, University of Colorado for the flight hardware and pre- and post-flight logistics provided, and ZGSi for the flight facilitation and support provided for participation in the ASGSR Annual Meeting.

[C17.1] Recent advances in modeling particle accumulation in periodic thermocapillary waves. H.C. Kuhlmann and R.V. Mukin¹.

¹ Vienna University of Technology, Vienna, Austria.

A flow in form of periodic rotating hydrothermal waves can be generated in liquid bridges and in droplets by differential heating along the free surface. Under certain conditions particles suspended to the liquid can rapidly form accumulation structures which co-rotate with the flow pattern. We present recent results of a numerical modeling of the particle accumulation phenomenon and compare these with experimental findings. In particular, we consider the characteristic particle-depletion zones from which particles are most rapidly removed, toroidal regions within which particles can move for a very long time before being removed, and line-like particle accumulation structures which are the hallmark of the accumulation phenomenon. Based on the favorable comparison with the experimental results we argue that the accumulation is due to a thin layer below the free surface where the motion of the particles experiences a significant dissipation. We find that the particle accumulation is a one-particle phenomenon which can be described by a dissipative dynamical system which exhibits different kind of attractors.

Supported by ESA (4000103003), BMVIT through FFG (3604313, 840119), and ZID of Vienna University of Technology.

[C17.2] Correlation between dynamics surface deformations and particle accumulation structure (PAS) in HZ Liquid Bridge. M. Suzuki¹ and I. Ueno²,³.

¹ Division of Mechanical Engineering, School of Science & Technology, Tokyo University of Science, Noda, Chiba, Japan, ² Department of Mechanical Engineering, Faculty of Science & Technology, Tokyo University of Science, Noda, Chiba, Japan, ³ Research Institute for Science & Technology (RIST), Tokyo University of Science, Noda, Chiba, Japan.

This study has been performed in the frame of preparing the incoming space experiment on flow patterns accompanying with the dynamic deformation in half-zone (H2) liquid bridge known as ‘Dynamic Surf.’ We especially focus on the particle accumulation structure (PAS) due to thermocapillary flow in the liquid bridge to indicate a spatio-temporal correlation between the PAS and the liquid bridge deformation. The liquid bridge is formed between top and bottom coaxial cylindrical rods. The thermocapillary-driven flow is induced by heating the top rod and cooling the bottom one to realize a designated temperature difference between the end walls of the liquid bridge. We employ 2-cSt silicone oil (Pr=28.1) as the test fluid, and we visualize the convection in the liquid bridge by putting gold-coated acrylic particles in the test fluid. It has been known that the induced flow exhibits a transition from the two-dimensional time-independent flow to the three-dimensional time-dependent ‘oscillatory’ one, and that the particles gather along closed orbits in the liquid bridge to form the PAS under a certain range of the intensity of the thermocapillary effect beyond the transition point. We employ two pairs of the high-speed cameras to visualize the flow pattern, and a laser displacement sensor to detect the dynamic surface deformation, and an infrared camera to measure surface temperature distribution in order to grasp a spatio-temporal...
correlation among the behaviors of the particle on the PAS, the surface deformation of the liquid bridge and the surface temperature known as the hydrothermal wave. We focus on two different types of the PAS; the PAS realized in the first regime of the traveling flow at rather small thermocapillary effect (referred as 'low-Ma PAS') and the PAS in the second regime at larger thermocapillary effect (referred as 'SL-1 PAS' after Tanaka et al. (PoF 2006)). We illustrate the ‘map’ of the deformation accompanying with the surface temperature and the PAS over the free surface, and make comparisons with the existing researches on the flow fields and the dynamic deformation just above the transition point by the experiment as well as the linear stability analysis.

[C17.4] Tangential Vibration Effect on Liquid-Gas (Liquid-Vapor) Interface Shape at Different Gravity Levels. T. Lyubimova1,2, D. Beysens1,4, and G. Gandikota3. 1 Institute of Continuous Media Mechanics UB RAS, Perm, Russia; 2 Perm State University, Perm, Russia; 3 CEA-ESEME, ESPCI-PMMH, Paris, France; 4 SBT, UMR-E CEA / UJF-Grenoble 1, INAC, Grenoble, France.

It is known that vibrations are able to stabilize the equilibrium states which were unstable in the absence of vibrations and to create new equilibrium states. The simplest example of this is the Kapitza’s pendulum which is the pendulum with the pivot point oscillating in vertical direction: it was shown that vertical high frequency vibrations of the suspension point can stabilize the state with the inverted bob position, i.e. the state with the bob above the point of suspension [1,2]. A similar effect was observed for hydrodynamical systems: the vertical vibration of a high enough intensity could stabilize the equilibrium of a two-layer liquid-gas hydrodynamical system: the vertical vibration of a high enough point of suspension [1,2]. A similar effect was observed for the inverted bob position, i.e. the state with the bob above the free surface, and make comparisons with the existing researches on the flow fields and the dynamic deformation just above the transition point by the experiment as well as the linear stability analysis.

Concurrent Session 18: Materials Science 5
Session Chair: Jonghyun Lee, University of Massachusetts, Amherst
Time: Tuesday, 2:00 pm – 3:30 pm

[C18.1] Thermophysical Property Measurements Under Reduced Gravity Conditions: Status of the ThermoLab-ISS and ThermoProp Projects. H.-J. Fecht1, R. K. Wunderlich1, L. Battezzati2, E. Ricci3, R. Novakovic3, J. Etay4, S. Seetharaman5 and J. Brillo6. 1 Universität Ulm, Institute of micro and nanomaterials. 89081 Ulm, Germany; 2 Universität Dortmund, Dipartimento di Chimica Inorganica, Chimica Fisica e Chimica dei Materiali, Torino, Italy; 3 CNR-ITEN, Genoa, Italy; 4 CNRS, SIMAP-ERM, PHELMA-Campus, Grenoble, France ; 5 KTH Royal Institute of Technology, Department of Materials Science and Engineering, Stockholm, Sweden; 6 Deutsches Zentrum für Luft- und Raumfahrt, Institut für Materialphysik im Weltraum, 51170 Cologne, Germany.

Thermophysical property values of complex alloys in the liquid phase provide important input data for the modelling of casting and solidification in industrial metallurgical processes. Owing to the difficulty of handling metallic alloys in the liquid phase in the relevant high temperature regimes accurate thermophysical property values in the liquid phase are generally unknown. The ThermoLab project was conceived to alleviate this need by using containerless processing techniques based on electromagnetic levitation in ground based laboratory and under reduced gravity conditions for thermophysical property measurements between roughly 1000 and 2000 °C. In addition, a ground based measurement programme using conventional thermoanalytic methods has been initiated.

Temperature dependent data of interest include calorimetric properties, density, surface tension and viscosity and the electrical conductivity. Alloys of interest are, for example, Ti-based light-weight alloys, Fe-alloys, Ni-based superalloys and Cu-alloys. In the course of the project extensive use was made of parabolic flights for the measurement of the surface tension and the viscosity and of Texus sounding rocket flights. In addition to the experimental programme ThermoLab is concerned with the modelling of non-contact thermophysical property measurements in an electromagnetic levitation device including the development and verification of non-contact calorimetry and considerations of the influence of fluid flow on viscosity measurements by the oscillating drop method. Another aspect of modelling is concerned with the surface tension in particular the influence of surface active elements on the temperature dependence of the surface tension and with the calculation of phase diagrams. An overview will be given of the current status of this truly international project and the progress towards implementation on the International Space Station in the years to come and supported by ESA, DLR, NASA, JAXA and ROSKOSMOS.
[C18.2] Preparation of Thermoanalytical Experiments on Liquid Metals for Processing on the ISS. R. K. Wunderlich, S. Schneider, J. Schmitz, D. Matson and H.-I. Fecht. Institut für Mikro- und Nanomaterialien, Universität Ulm, Ulm, Germany. The Materials Science Laboratory Electromagnetic Levitator, MSL-EML, is a complex instrument designed for the containerless processing of liquid metals for the measurements of a large variety of thermophysical properties. The MSL – EML will be installed on the ISS in early 2014 and is expected to become operational in mid-2014. Liquid metal droplets will be processed in a temperature range from 700 – 1900°C for the measurement of the specific heat capacity, surface tension and viscosity and various undercooling and nucleation investigations. For the safe and successful conduction of the experiments a thorough testing of methods and a thermophysical characterization of the specimen to be processed on the ISS were performed in a ground based experimental programme at DLR Cologne. In this contribution we describe the experiments to be performed on a generic high alloyed steel, some of the experimental methods such as non-contact electromagnetic induction calorimetry and the ground based experimental programme leading from concept to actual facility control parameters to conduct the experiments including safety issues. Supported by the Contract 4200014306 European Space Agency MAP Programme, 50WM1170 German Aerospace Center DLR Germany, NNX08AL21G and NNX10AV27G National Aeronautics and Space Administration, NASA, USA.

We thank DLR and Novespace for the PF campaigns and the MUSC team for the help with experiments. Financial support from DLR project 50WM1036 is gratefully acknowledged.

[C18.3] Thermophysical properties of highly doped Si_{1-x}Ge_{x} alloys under μg conditions. B. Damaschke, Y. Luo, N. V. Abrosimov, M. Czupalla, and K. Samwer. I. Physics Institute of University Göttingen, Leibniz Institute of Crystal Growth Berlin, Germany. We are preparing an experiment to measure thermophysical properties of Si_{1-x}Ge_{x} melts (x=0.25, 0.5, 0.75 and 1.0) on board of the International Space Station (ISS) under microgravity (μg) and electromagnetic levitation (EML) conditions, where the absence of gravity-driven convection and segregation of the components allows precision measurements of the thermal expansion, surface tension and viscosity as function of temperature. The semiconductor alloy crystals were prepared by means of Czochralski growth with B-doping in the range of 1.6–1.9x10^{20} at./cm^{3}. The high doping concentration ensures a low electrical resistivity (0.2–0.4 mΩcm) and thus the heating and the levitation of the samples in the MSL-EML. For the preparation, parabolic flight campaigns, which provided a μg condition for about 20 seconds, were carried out. Preliminary data of the density, thermal expansion and surface tension in the melt and undercooled state were obtained. The density shows a non-ideal behavior with the concentration and the highest value occurs at x=0.5, suggesting a relatively strong ordering tendency. We report about sample characterization and the status of the project concerning the ISS experiments. The initial results demonstrate that the melts of the semiconductor alloys can be successfully processed in the MSL-EML facility for precision measurements on board the ISS.

This work was supported by JAXA and JSPS KAKENHI No. 24360316.

[C18.4] Surface Oscillation Analysis of Levitated Liquid Droplets under Microgravity for Precise Thermophysical Property Measurement of High-Temperature Liquids. Masahito Watanabe, Shumpei Ozawa, Akitoshi Mizuno, and Akitoshi Ishikawa. Chiba Institute of Technology, Tokyo, Japan. Oscillating drop method with levitation technique under the microgravity conditions has advantage of thermophysical properties measurements high-temperature liquids. We are planning thermophysical properties of high-temperature melts in the International Space Station (ISS) using the materials-science laboratory-electromagnetic levitator (MSL-EML). Using MSL-EML we obtain the surface tension from the surface oscillation frequency and also the viscosity from the dumping time of the surface oscillations under the microgravity conditions. However, analysis of oscillating drop method in EML must be improved even in the microgravity conditions, because on the EML conditions the electromagnetic force (EMF) cannot generate the surface oscillation with discretely oscillation mode. Since under microgravity the levitated droplet shape is completely spherical, the surface oscillation frequency with different oscillation modes degenerates into the single frequency. Therefore, surface tension will not be affected the EML condition under microgravity, but viscosity will be affected on the different oscillation mode of surface oscillations. Because dumping time of surface oscillation of liquid droplets depends on the oscillation modes, the case of surface oscillation including multi oscillation modes the viscosity values obtained from dumping time will be modified from the correct viscosity. Therefore, we investigate the dumping time of surface oscillation of levitated droplets with different oscillation modes and also with including multi oscillation modes using electrostatic levitation (ESL) on ground and EML under microgravity conditions by the parabolic flight of airplane. The different EMF conditions generated the different surface oscillations with multi oscillation modes. From both levitation experiments, we obtained the different dumping time depending on the external force conditions. From the precise analysis of the dumping time difference, we discuss about that how does the dumping time modification by the oscillation mode conditions effect on the viscosity values. We also discuss the collection model of surface oscillation dumping for the case of multi oscillation modes generated in droplets.

This work was supported by JAXA and JSPS KAKENHI No. 24360316.
of surface tension on oxygen partial pressure ($P_{O_2}$) must be considered for industrial application of surface tension values. Effect of $P_{O_2}$ on surface tension would apparently change viscosity from the damping oscillation model. Therefore, surface tension and viscosity must be measured simultaneously in the same atmospheric conditions. In our group, using the parabolic flight levitation experimental facilities (PFLEX) the effect of $P_{O_2}$ on surface oscillation of levitated liquid droplets was systematically investigated for the precise measurements of surface tension and viscosity of high temperature liquids for future ISS experiments. We performed the observation of surface oscillations of levitated liquid alloys using PFLEX on board flight experiments by Gulfstream II (G-II) airplane operated by DAS. These observations were performed under the controlled $P_{O_2}$ conditions. We control the $P_{O_2}$ values in the process chamber using the oxygen sensing and controlled (OSC) device based on the stabilized zirconia tube. For precise control of $P_{O_2}$ we have been developed the collection method of the OSC device based on the equilibrium $P_{O_2}$ by gas mixture, Ar–He–H$_2$O–H$_2$ or Ar–He–CO$_2$–CO. Using the collection method of the OSC device, we controlled $P_{O_2}$ conditions in the atmosphere during measurements of the surface oscillation. We obtained the density, the viscosity and the surface tension values of liquid Cu base alloys. From these results, we discuss about the difference of surface oscillations with the change of the $P_{O_2}$ conditions.

This work was supported by JAXA and JSPS KAKENHI No. 24360316.

**Concurrent Session 19: Biophysics 1**

**Session Chair:** Theresa Miller, NASA  
**Time:** Tuesday, 2:00 pm – 3:30 pm

**[C19.1] Can Solution Supersaturation Affect Protein Crystal Quality?**  
S. Gorti, George C. Marshall Space Flight Center, National Aeronautics and Space Administration, Huntsville, AL 35812.

The formation of large protein crystals of “high quality” is considered a characteristic manifestation of microgravity. The physical processes that predict the formation of large, high quality protein crystals in the microgravity environment of space are considered rooted in the existence of a “depletion zone” in the vicinity of crystal. Namely, it is considered reasonable that crystal quality suffers in earth-grown crystals as a result of the incorporation of large aggregates, micro-crystals and/or large quality suffers in earth-grown crystals as a result of the vicinity of crystal. Namely, it is considered reasonable that crystal growth rate dispersion is reduced in microgravity-grown crystals. Growth rate dispersion is reduced in microgravity due to the diffusive rather than convective flow regime that delivers macromolecules to the crystal. By determining the magnitude of growth-rate dispersion on the ground, we aim for a predictive measurement of likely success on orbit. Crystal growth experiments are of small volume and mass, easily automated, and the samples are largely protected from re-entry forces in their fluid environment. They are easily transported for analysis and have a high potential for both scientific and commercial impact. The development of a predictive technique has the potential to substantially increase the scientific payback from these experiments and maximize the effective use of facilities. We discuss our observations and the work underway to test and prove our hypothesis.
This presentation will review two future microgravity experiments. The first experiment has a projected launch date of December, 2013 and is titled “Comprehensive Evaluation of Microgravity Protein Crystallization”. The purpose of the proposed study is to unambiguously demonstrate the scientific and commercial value of protein crystallization using a long-duration microgravity mission (i.e. 8-18 weeks duration on ISS). This will be accomplished using flight hardware that accommodates a statistically relevant number of high-value proteins (approximately 100 aqueous & membrane proteins) combined with comprehensive crystal quality analysis for microgravity versus 1-g control experiments. The experiments will be performed as a "blind" analysis using coded samples for the flight and ground control samples. A secondary goal will involve participation of high school and undergraduate students which includes 1) receive lectures on structural biology, theory and experimental aspects of crystallization and x-ray crystallographic structure determination, 2) design of 1-g and u-g experiments with one or more proteins (this will involve laboratory preparation for both 1-g and u-g experiments) and 3) participate in the microscopic and x-ray analysis of crystals grown in the flight hardware.

The second flight experiment involves investigation of two theories proposed to explain previously observed microgravity protein crystal improvements. One theory involves measurement of protein transport and crystal growth rates (it has been proposed that the improved crystal quality is due to slower protein transport to the growing crystal surface). The second theory proposes that there is an exclusion of larger protein aggregates incorporated into the growing crystal (aggregates produce crystal defects that reduce crystal quality). The theoretical explanation is based on the expected faster transport of single protein molecules as opposed to aggregates of two or more protein molecules. Unfortunately, there is insufficient experimental data to validate either theory. This second flight experiment will utilize the Light Microscopy Module (LMM) optical systems to explore via a series of experiments, the validity of each theory, thereby addressing the void in our understanding of microgravity’s effect on growing protein crystals. Supported by NASA GRANTS: 13-13CFStep2-0022 and NNJ12HA74G and NIH GRANT: R01GM095639.
[C20.1] Decreased Mortality Rate of Mice Challenged with Serially in vitro Passage of Starved Pseudomonas aeruginosa Strain. Tesfaye Belay. School of Arts and Sciences, Bluefield State College, Bluefield, WV, USA.

National Aeronautics and Space Administration (NASA) is interested in studying Pseudomonas aeruginosa because it causes opportunistic infection in astronauts during space flight. This opportunistic bacterium is often detected in the water system of space shuttle but its behavior and existence mechanism in water is not well defined. To promote our understanding of the mechanisms of P. aeruginosa colonizing the water supply of a space craft, the survival kinetics in sterile water and the pathogenicity of starved strains of P. aeruginosa in a mouse model is underway in our laboratory. Infection experiments showed that starved P. aeruginosa resulted in reduced death rate of mice compared to stock culture of the parental strain, ATCC 12055. The purposes of this study were to determine organ loads of P. aeruginosa and its virulence during in vitro serial passage of the starved strain. To determine whether in vitro passage would result in further weakening of virulence in mice, long-term starved P. aeruginosa in water were passaged for a week in vitro and Swiss Webster were inoculated intraperitoneal with lethal doses. Ninety percent of mice inoculated with the passaged starved cells survived the infection, compared to the survival of thirty percent of mice receiving the stock culture (P<0.05). Dead or sacrificed mice had a large amount of P. aeruginosa cells present in the liver, kidney, heart, lung and spleen. Formalin-killed P. aeruginosa starved cells resulted in 90% protection in mice challenged with a lethal dose of the parental strain compared to 0% protection compared to non-immunized control (P<0.05). Lethality was higher in mice inoculated with non-starved cells compared to mice infected with starved cells indicating that the characteristic of starved P. aeruginosa had changed may be due to the loss of some of its natural virulence features. Studies are underway to determine the mechanism(s) of protection. These results suggest that it is possible to reduce the virulence of starved cells of P. aeruginosa in mice through serial in vitro passage, which may be used for vaccine development, but further investigation is needed to truly understand the starvation adaptation and reduced pathogenesis of starved cells of P. aeruginosa.

Supported by NIH Grant SP20RR016477 to the West Virginia IDeA Network for Biomedical Research Excellence and NASA West Virginia Space Grant Consortium/NASA WV EPSCoR.


An NRC decadal survey issued in 2011 emphasized the importance of using cutting edge technologies to explore physiological, cellular and molecular mechanisms, and countermeasures to better understand the adverse effects of long duration spaceflight on mammals. A Science Working Group comprised of veterinarians and spaceflight investigators provided scientific and animal welfare guidance to NASA’s Rodent Habitat project, leading to the definition of success criteria for both hardware and operations on the ISS; these criteria include daily visual health checks, body weight measurements, and tissue analyses after on-orbit preservation. Here we report results from ground-based tests conducted to verify the utility of the Rodent Habitat for supporting ISS research using mice and rats as experimental models.

To test the ability of the transporter hardware to deliver healthy mice to the ISS on an unmanned vehicle, 20 mice (C57Bl/6J, 16 wk old, female) were housed inside the hardware for 10 days. Body weight measurements and visual health checks demonstrated that the hardware supported animal health and welfare. To test the acute effects of air transportation prior to launch (which might be required for future flight or ground controls), mice were shipped from a commercial vendor to ARC via air, and within 48 hours of arrival, the mice were either normally loaded (controls) or hindlimb unloaded to simulate weightlessness. At the end of the test (10 days), the body weights of the unloaded animals were lower compared to controls by 5-10% (as expected) and the veterinarian deemed the animals healthy and suitable for scientific research. Taken together, these results demonstrated that C57Bl/6J mice tolerated possible transportation conditions prior to arrival on ISS. Future verification tests will include launch simulation, long-duration biocompatibility in the hardware, and analysis of RNA quality (spleen) and enzyme contents and activity (liver) under conditions that simulate operations on the ISS.

In conclusion, ground-based verification tests conducted to date show that the modified hardware and operations support various activities planned for an upcoming validation flight; for the first time, the future validation study on ISS will provide in-flight sample preservation after long duration (>30 days) exposure of rodents to spaceflight.

Supported by NASA-02090.

[C20.3] X-Ray Movie Visualization for Differential Thresholds of Mouse Adaptation to Low Gravities. Y. Kumei1, J.L. Zeredo1-3, K.A. Inoue1, K. Hasegawa4, and S. Aou3. 1Tokyo Medical and Dental University, JAPAN, 2University of Brasilia, BRAZIL, 3Cambridge University, UK, 4JAXA/Institute of Space and Astronautical Science, JAPAN, 5Kyushu Institute of Technology, JAPAN.

We have developed a brand-new X-ray movie system to be used for mouse experiments. The system is composed of two X-ray irradiation instruments, image intensifiers, high-speed camera (~1000 fps) and video camera/recorder. Its super-high resolution (~1000 times higher than conventional apparatuses) creates sharp outline of anatomical images in mouse skeleton and viscera. The X-ray movie system can track in details the posture, locomotion, exploration, and other behaviors such as eating, drinking and grooming. Food intake, mastication, and swallowing can be visualized along the esophagus and stomach on X-ray movie. The X-ray movie can also monitor diaphragm and cardiac movement at the same time, which shows respiration frequency and heart rate instantly. Free-moving young male C57Bl/6J mice were exposed to graded levels of partial/low gravities (0.6, 0.3G, 0.15G, 0G) aboard parabolic flights. During the low-gravity exposure and the 1G level-flight, mouse skeletal/postural alterations as well as visceral movements were monitored noninvasively by the X-ray movie system. Skeletal/postural adaptation to low gravity changed dramatically around 0.15G, whereas the respiratory and heart rate changed between 0.6G and 0.3G. We also found the jaw closing/opening reflex was altered at gravities lower than 0.15G, which suggested that activity in the anti-
gravity muscle masseter was affected by these low-gravity levels (<0.15G). Data obtained from the x-ray movie system have shown for the first time that organs and tissues differ in the sensitivity or adaptation threshold to low-gravity. 

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Concurrent Session 21: Plants 2
Session Chair: Melanie Correll, University of Florida
Time: Tuesday, 4:00 pm – 5:00 pm


How plants respond to gravity is a fundamental biological question with important implications for space flight. Multiple lines of evidence in Arabidopsis and other model plants support the theory that the heavy, starch-filled organelles called amyloplasts serve as statoliths in the root tip and in the endodermal cell layer of the stem (Blancaflor et al., 1998; Tanaka et al., 2002; Tsugeki and Fedoroff, 1999). In the phosphoglucomutase (pgm-1) mutant, amyloplasts starch content is dramatically reduced and plants respond extremely slowly to a gravity stimulus (Caspar and Pickard, 1989; Kiss et al., 1996; Wolverton et al., 2011). However, the exact nature of the amyloplast-derived signal remains unknown. We have been studying a family of mechanosensitive channels localized to the envelope of endosymbiotic organelles (chloroplasts and mitochondria). Two of these channels, MSL2 and MSL3, are localized to the plastid envelope, where they are required for normal size, shape, and osmoregulation (Haswell et al., 2006; Veley et al., 2012). In msl2 msl3 mutants plastids are under hypoosmotic stress, causing them to become greatly enlarged and round, and they resemble over-inflated balloons. While msl2 msl3 double mutant plants appear to have normal gravity response, we have recently discovered that msl2 msl3 pgm-1 triple mutants plants do not. The triple mutant shows highly abnormal shoot and root growth. The main stem exhibits a “zig-zag” growth pattern similar to that previously observed in the zig (Morita et al., 2002; Yano et al., 2003) and AtLazy mutants (Yoshihara et al., 2013). Axillary stems often point down, then trail on the soil in a circular or undulating pattern. Root growth pattern appears to be completely random with respect to gravity. We hypothesize that the endodermal and root tip plastids in the msl2 msl3 pgm-1 triple mutant are so large and so light that they produce an incorrect signal, telling the plant that up is down, and directing growth in the wrong direction. We are currently analyzing plastid morphology, localization, and dynamic movement in this mutant and its wild type siblings. 

Supported by NNX13AM55G: Research Opportunities in Space Biology.

[C21.2] A Gradient of Extracellular Nucleotides Directs Polarization in Early Growth and Development of Ceratopteris Spores. Ashley E. Cannon, Greg Clark, Stanley J. Roux. Section of Molecular Cell and Developmental Biology, The University of Texas at Austin, TX 78712, USA.

Polarization is essential for most cells during development. Many studies have shown that gravity directs the polarization of Ceratopteris spores and that a visible representation of this effect is the emergence of a rhizoid pointing downward about 72 hours after germination begins. This polarized event requires a trans-cell calcium current that starts with calcium entering at the bottom of the spore before exiting through the top and runs parallel to the vector of gravity. Recent data have shown that extracellular nucleotides can affect the gravity response and the rate of rhizoid growth in Ceratopteris spores. Additionally, a purinoreceptor antagonist, pyridoxal-phosphate-6-azophenyl-2, 4-disulfonate (PPADS), can affect the gravity response even if it is only present during the first ten hours of germination. These data suggest that extracellular nucleotides play a role in regulating the gravity response and growth in Ceratopteris spores just as they do in Arabidopsis thaliana. Many studies have shown that gravity can induce the opening of stretch activated channels and that the opening of these channels permits the release of ATP. These results led us to hypothesize that as a result of gravity, mechanosensitive channels preferentially open along the bottom of the spore and release ATP. This asymmetrical distribution of extracellular ATP could potentially direct where calcium enters the cell. Also, blocking extracellular ATP receptors with PPADS blocks the ability of gravity to direct the steps necessary for the downward growth of rhizoids. When spores are exposed to an artificial gradient of extracellular nucleotides, the rhizoids tended to grow towards the source of the gradient. Collectively, these results support the hypothesis that preferential release and subsequent gradient of extracellular nucleotides is involved in the polarization of Ceratopteris spores. Information about the early signaling events that lead to gravity directed polarization will aid in the development of systems and techniques that future astronauts can use to grow plants in space. This will become important on long-term missions and during extended spaceflight.

Supported by The University of Texas and The National Science Foundation.

[C21.3] Gravity stress in non-statoctye plant cells. Youssef Chebli1, Théo Duquesne2, Lauranne Pujol, Anahid Shojaeifard3, Jack J.W.A van Loon4, Anja Geitmann1: 1 Institut de recherche en biologie végétale, Département de sciences biologiques, Université de Montréal, Montréal, Québec, Canada; 2 Department of Craniofacial Surgery & Oral Cell Biology, Academisch Centrum, Tandheelkunde Amsterdam (ACTA), University of Amsterdam and Vrije Universiteit Amsterdam, Research Institute MOVE, Amsterdam, The Netherlands; 3 Life and Physical Sciences Instrumentation and Life Support Section (TEC-MMG), European Space Agency (ESA), Noordwijk, The Netherlands.

Plants are able to perceive gravity stimulation and to respond to this trigger. Several mechanisms have been invoked to explain how plant cells perceive the direction and strength of the gravity vector and statolith based perception is well characterized. However, most plant cells are not equipped with statoliths and it is poorly understood, how they perceive and are able to respond to gravity related signals. Modulation in the synthesis and deposition of the cell wall is a common response to gravity-induced stress in plant cells, and this response is particularly pertinent as it is directed to mechanically counteract the effect of the gravity-induced compression or bending load. To understand how increased gravity acts on cell wall assembly proper we investigated one of the most rapidly growing plant cells, the pollen tube. This cellular...
protuberance is formed by the pollen grain to deliver the sperm cells to the ovules for fertilization and it can easily be cultivated in vitro. The main metabolic activity of the pollen tube is the synthesis and the deposition of cell wall precursors. Cell wall assembly in this cell is spatially confined to its tip and occurs at extremely high rates allowing for short term experiments. We monitored the effect of hyper-gravity and simulated microgravity (through omnidirectional exposure to gravity) on pollen tube growth, cell wall assembly, and intracellular transport using bright field and epi-fluorescence illumination. Live cell imaging was enabled by placing the remote controlled microscope in the Large Diameter Centrifuge (LDC) facility operated at the labs of the European Space Agency, ESA.

Acknowledgments: We would like to acknowledge the support of the ESA Spin-Your-Thesis (SYT) educational program and Mr. Alan Dowson from ESAESTEC-TEC-MMG for his assistance.

[C21.4] Long-Range Systemic Stress Signaling in Plants by Ca2+ Waves. Won-Gyu Choi, Masatsugu Toyota, Su-Hwa Kim, Richard Hilleary, and Simon Gilroy. Department of Botany, University of Wisconsin, Birge Hall, 430 Lincoln Drive, Madison, WI 53706, USA. Plants are exquisitely sensitive to their environment, rapidly integrating signals to appropriate developmental and physiological responses throughout the plant body. However, precisely how such information is transmitted within and between plant organs over the seconds-to-minutes timeframe remains poorly understood. Changes in cytoplasmic Ca2+ are well-recognized as signaling elements in plants and provide an attractive candidate for part of this systemic signaling system. For example, cooling of roots elicits Ca2+ increases in the shoot within minutes and distant wounding has been proposed to rapidly occlude phloem via a Ca2+-dependent mechanism. Therefore, to visualize how Ca2+ might act in local and systemic signaling, we generated Arabidopsis plants expressing GFP-based, cytoplasmic Ca2+ sensors of the Yellow Cameleon family. This analysis has revealed that plants possess an unexpected, rapid stress-signaling system based on Ca2+ waves that move from the site of stress perception (such as local wounding, or salt stress) to distant organs where they facilitate molecular responses. In response to salt stress of the root, these waves travel through the cortex and endodermis at up to 400 μm/sec, i.e. traversing several cells/sec. Blocking of the wave by local application of the channel blocker La3+ between site of wave initiation and distant target blocks rapid induction of stress-related transcripts. This observation suggests the Ca2+ wave carries information from one region of the plant rapidly to other more distal sites. Wave propagation is dependent on the vascular ion channel TPC1 and is regulated by reactive oxygen species (ROS) and the ROS-producing enzyme NADPH oxidase, (ATRBOHD). These observations suggest a ROS/Ca2+-dependent system may act as a long-range signaling system to rapidly integrate whole plant responses to localized stresses in the environment. Supported by NASA NNX09AK80G, NNX12AK79G and NSF 1121380.

[C22.1] Analysis of the Critical Marangoni Number Dependence with the Characteristic Length in High Prandtl Number Fluid. Shinichi Yoda1, S. Matsumoto2, A. Ueno2, and H. Kawasaki2,1 ISAS/JAXA, Sagamihara, Japan, 1Tokyo Uni. of Science, Noda, Japan. Many experiments to determine the critical Marangoni number at the onset of oscillatory flows with high Prandtl number (Pr) fluids have showed dependence of the diameter of the liquid column, although the aspect ratio of the column is the same. This fact contradicts the similarity principle in fluid physics. The Marangoni experiments have been being done to make clear what is Marangoni transition behavior by using Silicone oil with 50mm diam. The results were compared with previous experiment results with 30 mm diam. JAXA experiments of MEIS1 and 2 and 5mm diam. obtained on ground. The dependency of critical Marangoni number can be expressed by the order of 2/3 power of the critical number, which is in good agreement with our modeling by considering thermal boundary layer formed around the both heating and cooling desks. Different aspect ratio (Liquid length/Diam.) of 0.1 to 1.25 of liquid bridges was also studied by defining critical Marangoni number. The experiments has carried out as steps with 0.2K holding time of almost 60 min to get equilibrium condition in each step until oscillatory flow. The Prandtl number used in this experiments is 67, which is the as previous JAXA experiments, MEIS1 and 2. The results that can be concluded are as follows: 1) The critical Marangoni number vs aspect ration curves shows as follows; Firstly, critical Marangoni numbers decreases with increasing aspect ratio until 0.4 aspect ratio, and after that increases with increasing aspect ration having maximum value at around 1.25 aspect ratio. The critical Maranon number obtained here with 50mm diam. is larger than that with 30mm. This fact shows us our modeling is correct. The marangoni number dependence with the aspect ratio dependence can be explained by considering the thermal boundary layer. The tendency of the aspect ration dependence can be explained by numerical simulation as well as semi-quantitative analysis.

[C22.2] Recent Measurement of Soret Coefficients for Ternary Hydrocarbon Mixture on Board ISS. M.Z. Saghir1, Amirhosein Ahadi1, Quentin Galand2 and Stefan VanVaerenbergh2. 1Ryerson University, Toronto, Canada, 2Université Libre de Bruxelles, Brussels, Belgium.

While Soret coefficients of binary mixtures have been measured on board the International Space Station (ISS) successfully, for the first time, we report the Soret coefficient of a ternary mixture in a low gravity environment condition. The sample was contained in a cell 10 mm x 10 mm x 5 mm (w,l,h) and was monitored by means of a Mach-Zehnder interferometer at two wavelengths. The results of this experiment, which correspond to a mixture of 80% isobutylbenzene, 10% tetrahydrobenzaldehyde, and 10% dodecane by mass, are presented in this study. While perfect thermal isolation near the lateral walls was not obtained, the separation of the components in the mixture behaved in the same manner as pure diffusion at the central region of the cavity. The experiment known as Run7 is repeated (Run12) to verify the accuracy of the setup with a mean temperature of 298 K. The unique obtained results demonstrate the repeatability of thermodiffusion experiments in a microgravity environment. Almost equal separations of the
Molecular diffusion and thermodiffusion, or Soret diffusion, \[C22.3\] Review of ground and microgravity measurements of diffusion and Soret coefficients in multicomponent hydrocarbons. S. Van Vaerenbergh, M. Z. Saghir, Q. Galand, Microgravity Research Center, Université libre de Bruxelles, Service de Chémie Physique EP, Brussels, Belgium, Department of Mechanical and Industrial Engineering, Ryerson University, Toronto, Ontario Canada. Molecular diffusion and thermodiffusion, or Soret diffusion, coefficients constitute the set of dissipative coefficients providing all the diffusive properties of mixtures. In multicomponent systems, their measurements present several difficulties, one major being the sensitivity of the measurement to natural convection. The hydrocarbon mixtures present interest manifested by oil industry, particularly in the field of exploration. We review here the measurements and determination performed on these systems. Several approaches have been used in predicting and determining experimentally these coefficients based on the minimal set of coefficients. This minimal set is defined by non-equilibrium thermodynamics and equilibrium thermodynamic properties. Because of the dissipative character of these processes either non-equilibrium transport properties or experimental determination are needed. The theories predicting these coefficients are now abundantly illustrated in literature, and are not discussed here. Experiments are performed varying components, temperature, composition and also pressure. Several technics have been used with attempts to analyze the influence of the molecular structure on the effect for the Soret coefficients. Microgravity has been selected in the end to provide reference values of the Soret coefficients. These measurements have been performed in the SCCO experiment in 2007, and in the DSC-DCMIX experiment in 2010 and 2012. They complement the ground measurements that can be performed and allow to validate ground based technics. Microgravity measurements are also used in the DSC-DCMIX experiment to determine the isothermal diffusion coefficients. Supported by Belgian Prodex DSC-DCMIX.

**Concurrent Session 23: Materials Science 6**

*Session Chair:* James P. Downey, NASA Glenn Research Center

*Time:* Tuesday, 4:00 pm – 5:00 pm

\[C23.1\] Materials Sciences in ESAs ELIPS Programme. D. Voss, O. Minster, HESpace bv for European Space Agency, The Netherlands, European Space Agency, The Netherlands. The Materials Sciences research activities implemented by ESA in the framework of the European Life and Physical sciences in Space (ELIPS) programme build up on many years of scientific progress and experience with developing and operating instruments on various space carriers. The Materials Science programme focuses on two main topics, namely investigations of solidification phenomena and the measurements of thermo-physical properties. For the realisation of Materials Sciences experiments several platforms and facilities are utilised. This spans from centrifuges to - with increasing experiment duration - the Drop Tower in Bremen, the A-300 aircraft flying parabolic trajectories, sounding rockets and eventually the International Space Station (ISS). Several solidification instruments from typical Bridgman type furnaces, such as the Materials Science Laboratory and the Transparent Alloys Instrument, to electromagnetic levitation and heating of spherical samples (EML) were developed, some of which are already operational in orbit. A dedicated X-ray set-up has also recently been operated on a sounding rocket and parabolic flight to enable in-situ observations of the solidification of a metallic alloy. The presentation will provide an overview of Materials Science projects, their objectives and their international cooperation. The corresponding platforms and instruments available for Materials Science experimentation will be highlighted. The authors would like to thank all Materials Sciences international teams involved in the ESA ELIPS programme and their sponsoring agencies for the excellent cooperation over the last decade.

**Concurrent Session 24: Acceleration Measurements and Suborbital Flights**

*Session Chair:* Kenol Jules, NASA Glenn Research Center

*Time:* Tuesday, 4:00 pm – 5:00 pm

\[C24.1\] The ISS Microgravity Acceleration Environment. Kenneth Hrovat, Kevin McPherson, Eric Kelly, and Jennifer Keller. ZIN Technologies, Inc., USA; NASA Glenn Research Center, Cleveland, OH, USA. The National Aeronautics and Space Administration (NASA) Glenn Research Center (GRC) provides acceleration measurement and analysis support for International Space Station (ISS) investigators, and has been doing so for more than a decade. The measurement capability comes from two independent systems: the Space Acceleration Measurement System (SAMS) for the vibratory regime (0.01 ≤ f ≤ 300 Hz) in all three main laboratories, and the Microgravity Acceleration Measurement System (MAMS) for ubiquitous coverage of the quasi-steady regime (0 ≤ f < 0.01 Hz). The SAMS and MAMS both stream their acceleration measurement data to the NASA GRC Telescience Support Center in real-time in order to provide continuous coverage of the ISS acceleration environment. These resources are in place to support scientific payloads, technology development, and vehicle sustaining engineering. An overview and background information on the two acceleration measurement systems will be presented. In addition to direct measurement support, NASA GRC sponsors the Principal Investigator Microgravity Services (PIMS) project, which develops, operates, and maintains the processing, archival, and analysis infrastructure for the SAMS and MAMS acceleration data. These data flow from the ISS to ground systems at the NASA GRC in Cleveland, Ohio where dedicated hardware and software are in place to receive, archive, analyze, and distribute these acceleration data and analysis results via the web. Fundamental analysis is
geared for general characterization of the acceleration environment, and monitoring structural integrity, however, an array of acceleration analysis results will be presented along with topics on collaborative efforts between NASA GRC, NASA JSC, and JAXA. An update on the SAMS control unit upgrade will also be presented. This work is supported by the NASA Glenn Research Center, Code MSL and ZIN Technologies, Inc. under the SPACEDOC Contract.

[H24.2] JAXA Approach to Microgravity Environment Measurement in JEM.

Hayato Ohkuma1, Keiji Murakami1, Satoshi Matsumoto1, Kohichi Shibasaki2, Masayuki Goto1, and Keiichiro Sakagami1. 1Japan Aerospace Exploration Agency.

JAXA has measured microgravity environment in JEM by Microgravity Measurement Apparatus (MMA) since August, 2008. MMA has three remote sensors which are attached on the surface of the experiment rack (Ryutai Rack, Saibo Rack, Kobairo Rack). This measurement is mainly performed for two purposes. First purpose is providing microgravity environment data during experiment to researchers. The researchers use these data when they analyze experiment data. Second purpose is accumulating microgravity environment data at various vibratory event such as docking / undocking of transfer vehicle, communication antenna tracking and crew exercise. These data are used for estimation whether the disturbance have potential for impact on experiments. So the microgravity environment data collection and analysis are very important to success various experiment in JEM. Actually some of g-jitter affected JEM experiments. Especially Marangoni experiment (fluid physics experiment) is sensitive to g-jitter. JAXA plan this experiment only crew sleeping time in order to prevent g-jitter due to crew motion. Moreover we try to reduce g-jitter during Marangoni experiment. Therefore JAXA request NASA Micro-G team to collaborate on microgravity measurement and analysis. NASA has measured microgravity environment in JEM by Space Acceleration Measurement System (SAMS). And we discuss about the result of microgravity environment analysis after data collection. On the other hand, JAXA began measuring the microgravity environment at JEM exposed facility. This measurement is conducted by Microgravity Measurement Equipment (MME). MME has three sensors and installed in JEM exposed facility. JAXA performed MMA checkout at May 2013 and confirmed that receiving data was normal. So we officially measure microgravity environment at JEM exposed facility after time. We are going to investigate the correlation of g-jitter between JEM pressurized facility and exposed facility. As mentioned above, JAXA continue to measure and analyze microgravity environment in JEM and figure out the cause of g-jitter. Of course JAXA keep on collaborating with NASA. At last, JAXA sets to share the acceleration data on-orbit with NASA. The MMA data will be distributed to all researchers via PIMS web site. The PIMS web site address is “http://pims.grc.nasa.gov/pims_iss_index.html”.

[H24.3] MASER 12 a Microgravity Sounding Rocket Mission

Launched at Esrange. Christian Lockowandt1, Gunnar Florin1, Ylva Houltz2, Jimmy Thorstenson2. 1Swedish Space Corporation, P.O. Box 4207, SE-171 04 Solna, Sweden, christian.lockowandt@sscspace.com.

MASER is a sounding rocket platform for short-duration microgravity experiments, providing the scientific community with an excellent microgravity tool. The MASER programme has been running from 1987 and has up to 2012 provided successful flights for microgravity missions with 6-7 minutes of microgravity, the g-level is normally below 1x10^-5 g. The MASER 12 was launched on 13 February 2012 from Esrange Space Center in Northern Sweden. The rocket carried four ESA financed experiment modules. The MASER 12 vehicle was propelled by the 2-stage solid fuel VSB-30 rocket motor, which provided the 395 kg payload with an apogee of 260 km and 6 and a half minutes of microgravity. Swedish Space Corporation carried out the MASER 12 mission for the ESA. The payload accommodated the BIOMICS-2, BIM-2, XRMON-GF and SOURCE-2 experiment modules containing five experiments for scientific research, but also containing the Maser Service Module and the recovery system. The Service Module provided real-time 5 Mbps down-link of compressed experiment digital video data from five on-board cameras, as well as high-speed housekeeping telemetry data. The BIM-2 experiment module contains 2 life-science experiments, STIM of Dr A Cogoli and MicImmun of Pr Pepplenbosch. The STIM objective is to study signal transduction in human T-cells in microgravity. MicImmun objective is to study the influence of microgravity on the activation of NF-kB / Microgravity in adaptive immunity. The SOURCE-2 experiment module contains the fluid science experiment of Dr. Colin, Dreyer, Behruzi and Lacapère, studying convective boiling and condensation: local analysis and modeling of dynamics and transfers. The BIOMICS-2 experiment module contains the fluid/life science experiment of Dr Podgorski et al., studying dynamics of cells and biomimetic systems. The XRMON-GF (Gradient Furnace) experiment module contains the experiment of Dr Nguyen-Thi, aiming at live radiographic observation of directional solidification under microgravity. This experiment is executed within the frame of the ESA MAP programme. XFRMON experiment modules, using X-ray as diagnostic tool, were already flown on MASER 11 and MAXUS B. XRMON-GF is a new development.

This paper will report on the MASER programme and the MASER 12 mission contents focusing on the facilities. Project financed by ESA.
[C25.1] Low Gravity Cryogenic Liquid Acquisition for Space Exploration.  David J. Chato1, Jason W. Hartwig1, Enrique Rame2, John M. McQuillen1.  1NASA Glenn Research Center, Cleveland, OH, USA; 2National Center for Space Exploration Research, Cleveland, OH, USA.

NASA is currently developing propulsion system concepts for human exploration. These propulsion concepts will require the vapor free acquisition and delivery of the cryogenic propellants stored in the propulsion tanks during periods of microgravity to the exploration vehicles engines. Propellant management devices (PMD’s), such as screen channel capillary liquid acquisition devices (LAD’s), vanes and sponges currently are used for earth storable propellants in the Space Shuttle Orbiter and other spacecraft propulsion systems, but only very limited propellant management capability currently exists for cryogenic propellants. NASA is developing PMD technology as a part of their cryogenic propellant storage and transfer (CPST) project. System concept studies are looking at the key factors that dictate the size and shape of PMD devices and established screen channel LADs as an important component of PMD design. Normal gravity experiments and modeling are studying the behavior of the flow in LAD channel assemblies (as opposed to only prior testing of screen samples ) at the flow rates representative of actual engine service. Recently testing of LAD channels in liquid Hydrogen was completed. Three different types of test were conducted: Measurement of the pressure drop for flow through a one inch diameter screen sample; Measurement of the pressure drop in a horizontally-mounted rectangular LAD channel assembly at flow rates representative of a main engine firing; and determination of bubble breakthrough for flow into a partially-immersed vertically-mounted LAD channel. This presentation will present an overview of low gravity cryogenic liquid acquisition strategies, review the findings of this recent test series, and discuss the implications of the testing and studies to exploration mission concepts.

Supported by the Cryogenic Propellant Storage and Transfer project of NASA Space Technology Mission Directorate’s Technology Demonstration program.

[C25.2] Effect of Residual Noncondensables on Pressurization & Pressure Control of a Zero-Boil-Off Tank in Microgravity.  M. Kassemi1, S. Hylton2, O. Kartuzova2.  1National Center for Space Exploration (NCSE), NASA Glenn Research Center, Cleveland, OH 44135, USA.

The Zero-Boil-Off Tank (ZBOT) Experiment is a small-scale experiment that uses a transparent ventless Dewar and a transparent ventless Dewar and a transparent flat-plate simulated phase-change fluid to study sealed tank pressurization and pressure control with applications to on-surface and in-orbit storage of propellant cryogens. The experiment will be carried out under microgravity conditions aboard the International Space Station in the 2014 timeframe. This paper presents preliminary results from ZBOT’s ground-based research that focuses on the effects of residual noncondensable gases in the ullage on both pressurization and pressure reduction trends in the sealed Dewar. Tank pressurization is accomplished through heating of the test cell wall in the wetted and un-wetted regions simultaneously or separately. Pressure control is established through mixing and destratification of the bulk liquid using a temperature controlled forced jet flow with different degrees of liquid jet subcooling.

A Two-Dimensional axisymmetric two-phase CFD model for tank pressurization and pressure control is also presented. Numerical prediction of the model are compared to experimental 1g results to both validate the model and also indicate the effect of the noncondensable gas on evolution of pressure and temperature distributions in the ullage during pressurization and pressure control. Microgravity simulations case studies are also performed using the validated model to underscore and delineate the profound effect of the noncondensables on condensation rates and interfacial temperature distributions with serious implications for tank pressure control in reduced gravity.

Supported by NASA RID Grant Number NNX10AQ71A.

[C25.3] An Energy of Fluid Approach to Modeling Pressurization of a Non-Vent Storage Tank.  J.G. Marchetta1, A.P. Winter2, and F. Sabri2.  1Department of Mechanical Engineering, 2Department of Physics, The University of Memphis, Memphis, TN, USA.

The objective of current research is to continue developing a complete finite volume based CFD model of tank pressurization using an Energy of Fluid (EOF) approach. The increase in system pressure has several influencing factors such as that of percent liquid filling, gravity levels, rate of heat, and distribution of heat relative to the liquid.

In previous research efforts, a lumped thermodynamically based model of the ullage coupled to the transport equations in the liquid and a cell by cell mass balance along the interface was employed to account for the phase change process. These methods do not adequately account for the latent heat associated with the heat transfer with phase change problems. This has proven disadvantages when modeling phase interface. The EOF method can be directly applied to all heat transfer phase change problems including those that the value of latent heat is significantly larger than the sensible internal energy in the computational cell. This method uses the complete form of Navier-Stokes equations that includes all relevant phase change parameters such as the latent heat, surface tension, shear stress and gravity. The EOF method only requires a single set of governing equations that includes both the liquid and vapor phase for diabatic two phase flows.

Analytical data used to verify and validate the new model includes that of the classical Stefan problem. The test cases completed study the motion of the interface in time. Predictions are compared to that of available experimental data for a spherical liquid parahydrogen tank. The thermodynamic properties for parahydrogen, specifically the thermal conductivity, allow for the presence of the sub-cooled liquid and superheated vapor in the same container. A sequence of test case data for bulk evaporation is provided which shows pressure history as a function of heat added. A better understanding of the effect the heat added to the system has on the total internal energy of the system, and consequently the temperature distribution, allows for an enhanced prediction of total system pressure.

Supported by NASA ISS Physical Sciences Research Program, NASA HQ, USA.
[C25.4] Numerical Investigation of Frozen Wave Instability in Zero Gravity Conditions. T.P. Lubyimova1,2, and A.O. Ivantsyov1. 1Institute of Continuous Media Mechanics UB RAS, Perm, Russia; 2Perm State University, Perm, Russia.

In experiments [1] it was found that under sufficiently intensive horizontal vibrations the interface of two immiscible fluids subjected to the gravity field becomes unstable and the formation of the frozen wave is observed. The theoretical investigation of this phenomenon was carried out in [2] using high frequency approach. It was shown that the development of frozen waves is related to the Kelvin-Helmholtz instability and analytical formula for neutral curve was derived. The effect of the fluids viscosity on frozen wave development was analyzed in [3] and in [4] for equal viscosities and great viscosity contrast respectively.

The present work deals with the investigation of frozen wave formation in zero gravity conditions. The study is performed numerically using Volume of Fluid method. The calculations show that at the first stage of the process the interface structure is similar to the frozen wave observed in normal gravity conditions. The further evolution leads to the formations of the system of striates since in the absence of gravity there is no force that could limit the growth of interface deflection.

The calculations are performed for different parameters of fluids and different thickness of layers. The dependences of striates period on the fluid viscosities, vibration amplitude and height of the layers are obtained. Supported by the Government of Perm Region (Contract number C-26/212).


Concurrent Session 26: DECLIC (Session 3) – Solidification Studies on DECLIC

Session Chair: James P. Downey, NASA Glenn Research Center
Time: Wednesday, 8:00 am – 10:00 am

[C26.1] 3D-Alloy Solidification in DECLIC Directional Solidification Insert: Live monitoring of microstructure formation in microgravity. N. Bergeon1,2, F. Lisboa-Mota1,2, L. Chen1,2, D. Tourret3, J.-M. Debierré1,2, R. Guérin1,2, A. Karma3, B. Billia1,2, and R. Trivedi3. 1IM2NP, Aix-Marseille University, 2IM2NP, CNRS, Marseille, France, 3Physics Department, Northeastern University, Boston, USA, 4Department of Materials Science & Engineering, Iowa State University, USA.

To clarify and characterize the fundamental physical mechanisms active in the dynamical formation of three-dimensional (3D) arrays of cells and dendrites under diffusive growth conditions, in situ monitoring of series of experiments on transparent model alloy succinonitrile – 0.24 wt% camphor was carried out under low gravity in the DECLIC Directional Solidification Insert on-board the International Space Station. These experiments offered the very unique opportunity to in situ observe and characterize the whole development of the microstructure in extended 3D patterns. The experimental methods will be first described, including in particular the observation modes and the image analysis procedures developed to quantitatively characterize the patterns. Microgravity environment provided the conditions to get quantitative benchmark data: homogeneous patterns corresponding to homogeneous values of control parameters along the whole interface were obtained. The sequence of microstructure formation will be presented as well as the evolution of quantitative benchmark data that describe the pattern, such as primary spacing and order/disorder characteristics. The evolution of these data with the experimental parameters that control the growth in directional solidification, namely the thermal gradient and the pulling rate, will be compared to theoretical models. Time evolution of these parameters during the microstructure development will be also analysed to point out the mechanisms of spacing selection and adjustment.

Supported by French space agency CNES (Microstructures de solidification 3D - MISOL3D – project) and NASA (Dynamical selection of interface patterns - DSIP – project).

[C26.2] 3D-Alloy Solidification in DECLIC Directional Solidification Insert: Secondary instabilities observed in cellular growth. N. Bergeon1,2, L. Chen1,2, F. Lisboa-Mota1,2, D. Tourret3, J.-M. Debierré1,2, R. Guérin1,2, A. Karma3, B. Billia1,2, and R. Trivedi3. 1IM2NP, Aix-Marseille University, 2IM2NP, CNRS, Marseille, France, 3Physics Department, Northeastern University, Boston, USA, 4Department of Materials Science & Engineering, Iowa State University, USA.

To clarify and characterize the fundamental physical mechanisms active in the dynamical formation of three-dimensional (3D) arrays of cells and dendrites under diffusive growth conditions, in situ monitoring of series of experiments on transparent model alloy succinonitrile – 0.24 wt% camphor was carried out under low gravity in the DECLIC Directional Solidification Insert on-board the International Space Station. The extended homogeneous patterns obtained enabled us to observe secondary instabilities of the cellular pattern for the very first time in 3D patterns. For a restricted range of growth control parameters, the cellular pattern presents breathing oscillations that may affect the whole pattern. Oscillating cells are characterized by a periodic variation of both their appearing size (in the (x, y) plane) and of their tip position (in the vertical z direction). Up to know, such oscillating cellular pattern had been studied only in thin samples (M. Georgelin et al., Phys. Rev. Lett. 79, 2698 (1997)) and a global spatiotemporal coherence over large domains was exhibited by experiments. In contradistinction, present microgravity experiments reveal a richness of 3D breathing modes with limited spatiotemporal coherence only. Our analyses highlight the absence of global coherence of cell oscillations, excepting in locally ordered areas where synchronization of neighbor cells may happen. In another range of control parameters, another type of secondary instability has been identified that corresponds to multiplet formation; the structure and dynamics of those multiplets will also be described.

Supported by French space agency CNES (Microstructures de solidification 3D - MISOL3D – project) and NASA (Dynamical selection of interface patterns - DSIP – project).
Experiments were repeated on the same control parameters (solute concentration, applied temperature) to microgravity experiments processed with the same liquid interface. This can be achieved by comparing ground evidence of the influence of fluid flow on the formation, and selection of interface patterns (DSIP – project) of cells and dendrites under diffusive growth conditions, in situ monitoring of series of benchmark experiments on transparent samples on earth under gravity-driven fluid flow in the Engineering Systems, Northeastern University, Boston, MA, USA, Department of Materials Science & Engineering, Iowa State University, USA.

To clarify and characterize the fundamental physical mechanisms active in the dynamical formation of three-dimensional (3D) arrays of cells and dendrites under diffusive growth conditions, in situ monitoring of series of benchmark experiments on transparent samples on earth under gravity-driven fluid flow in the DECLIC Directional Solidification Insert on-board the International Space Station. These experiments have been complemented with quantitative phase-field numerical simulation. Indeed, materials properties are primarily governed by the growth microstructure so that it is critical to precisely control microstructure formation in solidification processing of alloys. Yet, on earth gravity-driven convection in the liquid phase most often plays an essential role in casting of metallic alloys. It is therefore demanded to evidence the influence of fluid flow on the formation, and selection when any, of the growth microstructure that forms at the solid-liquid interface. This can be achieved by comparing ground experiments to microgravity experiments processed with same control parameters (solute concentration, applied temperature gradient and pulling velocity). Accordingly, selected microgravity experiments were repeated on the same succinonitrile-camphor sample on earth under gravity-driven fluid flow in the Engineering Model of DECLIC-DSI. After a brief recall of experimental procedure, the evolution of primary spacing with time, pulling rate and temperature gradient will be detailed for both conditions. The comparison will in particular bring out specific effect of fluid flow coming from the low thermal conductivity (high Prandtl number) of succinonitrile. The influence of convection on array disorder in the formation of the 3D-patterns forming at the solid-liquid interface will be also discussed.

Supported by French space agency CNES (Microstructures de solidification 3D - MISOL3D – project) and NASA (Dynamical selection of interface patterns - DSIP – project).

3D-alloy solidification in DECLIC Directional Solidification Insert: Numerical simulation of microgravity experiments. D. Tourret, A. Karma, N. Bergeon, B. Billia, J.-M. Debierre, R. Guérin, L. Chen, A. Ramirez, R. Trivedi. 1Department of Physics and Center for Interdisciplinary Research on Complex Systems, Northeastern University, Boston, MA, USA, 2Aix-Marseille University, 3CNRS, IM2NP, UMR 7334, Marseille, France, 4Department of Materials Science & Engineering, Iowa State University, Ames, IA, USA.

Experiments within the microgravity environment of the DECLIC Directional Solidification Insert have provided new insights into the formation of complex interface patterns, for the first time in a three-dimensional homogeneous configuration. These unique observations highlighted numerous fascinating behaviors, including the existence of an oscillatory instability of growing cellular arrays. Earth-based experiments had so far suggested that breathing mode oscillations display a high level of spatiotemporal coherence over extended domains. The three-dimensional experiments in the DECLIC-DSI reveal the existence of noncoherent oscillations associated with spatially disordered arrays, with the exception of small ordered regions where cells locally undergo a coherent breathing mode instability.

We performed three-dimensional quantitative phase-field simulations that reproduced the oscillatory behavior with a remarkable accuracy for the oscillation period. Similarly as in the experiments, we found that the oscillation period is common to the entire array, even when cells do not oscillate in phase. However, when spatial ordering is imposed, sustained oscillatory breathing modes occur with a 120-degree phase shift between the three sublattices of cells in the case of a hexagonal honeycomb-like structure. A thorough computational study of steady-state cell shapes revealed that the oscillatory instability occurs in a very narrow spacing range and only for high temperature gradients when a stability gap opens up in the stable spacing range. Simulations also demonstrated that a global coherence of oscillations over extended domains may be sustained if the spatial order of the array persists. Furthermore, simulations and experiments showed that large amplitude oscillations cause cells to split, thereby promoting the permanent reordering of the array. This study highlighted the intrinsic link between spatiotemporal oscillation coherence and array ordering, and the crucial role of the tip splitting instability in preventing global ordering in a full three-dimensional configuration.

Work supported by NASA (Dynamical selection of interface patterns - DSIP – project) and the French space agency CNES (Microstructures de solidification 3D - MISOL3D – project).

3D-alloy solidification in DECLIC Directional Solidification Insert-R: Motivations for reflight and SPADES/MISOL3D project perspectives. A. Karma, D. Tourret, N. Bergeon, B. Billia, J.-M. Debierre, R. Guérin, L. Chen, A. Ramirez, R. Trivedi. 1Department of Physics and Center for Interdisciplinary Research on Complex Systems, Northeastern University, Boston, MA, USA, 2Aix-Marseille University, 3CNRS, IM2NP, UMR 7334, Marseille, France, 4Department of Materials Science & Engineering, Iowa State University, Ames, IA, USA.

By combining large-scale phase-field simulations and microgravity directional solidification experiments within the DECLIC-DSI, we have been able to identify and explain the oscillatory behavior of cellular arrays and their lack of global coherence at long spatial range due to dynamical spatial rearrangement of cells in the array. Simulations also confirmed that coherent dendritic side branching exists in a full three-dimensional configuration, as suggested experimentally and numerically in the literature for a thin-sample configuration, as well as in the SCN-0.24 wt%camphor alloy in the DSI experiments.

While the dendritic runs in the DSI campaign provided a valuable picture of the dendritic growth regime, they exhibited a significant curvature of the solidification front and dendrite tip radii were too small to be accurately measured by interferometry. For these reasons, the new DSI-R experiments will be performed with a higher composition alloy that produces dendritic structures in a lower velocity regime with minimized latent-heat effects and front curvature. We carried out preliminary phase-field studies on this alloy for a large range of control parameters in thin-sample experiments on earth. Results of experiments and simulations show
that dendrites form at lower velocities and with a larger tip radius that can be directly measured by interferometry.

The new set of experiments in the DSI-R is aimed at investigating the formation of well-developed dendritic array structures of direct technological relevance for the solidification and casting industry. The experiments will focus on elucidating (i) the fundamental mechanism of sidebranch formation, (ii) the interaction of primary array and the secondary sidebranch structures, (iii) the mechanism of the cell to dendrite transition, and (iv) the dependence of cell and dendrite tip shapes on growth conditions. Combined with phase-field simulations, those studies should bring significant progress in understanding the origin of side-branching and the nature of the cell to dendrite transition, which have been a long standing issues in solidification for several decades.

Work supported by NASA (Dynamical selection of interface patterns - DSIP & Spatiotemporal Evolution of Three-Dimensional Dendritic Array Structures - SPADES - projects) and the French space agency CNES (Microstructures de solidification 3D - MISOL3D - project).

[C26.6] 3D-alloy solidification in DECLIC Directional Solidification Insert: 1g-experiments on thin samples versus 3D-experiments in µg. R. Trivedi¹, L.M. Fabietti¹, J. Gu², M. Xu³, N. Bergeon²,³, D. Tourret⁴, J.-M. Debierre²,³, R. Guérin²,³, L. Chen²,³, B. Billia²,³, A. Karma⁴. ¹Department of Materials Science & Engineering, Iowa State University, Ames, IA, USA, ²Aix-Marseille University, ³CNRS, IM2NP, UMR 7334, Marseille, France, ⁴Department of Physics and Center for Interdisciplinary Research on Complex Systems, Northeastern University, Boston, MA, USA.

The presence of fluid flow during the solidification of bulk samples under 1g conditions strongly influences the microstructure evolution dynamics and the final microstructural characteristics that govern the properties of the solidified alloy. Thus, fundamental understanding of microstructure formation under diffusive growth conditions under 1g conditions is generally examined in thin samples where fluid flow effects are negligible. Recently, experiments within the microgravity environment of the DECLIC/DSI have provided for the first time benchmark data in 3D that will be compared with the ground-based results in thin samples. Experiments were carried out in thin samples under identical conditions of growth rate, thermal gradient and composition, as in the µg experiments. The results on the planar interface instability, the dynamics of cellular and dendritic pattern evolution, the time evolution of primary spacing, the regime of oscillatory behavior for cells, and the tip radius of cells and dendrites have been quantitatively characterized and compared with the microgravity results to assess the applicability of the results from finite sample thickness to bulk samples.

For precise quantitative analysis of the results from microgravity experiments it is critical to know accurately the values of the relevant physical constants and the phase diagram parameters that are required in the application of the theoretical model. These parameters are generally measured under 1g conditions where they could be influenced by any fluid flow that may be present. Specifically the value of the diffusion coefficient is quite sensitive to the presence of fluid flow and a large scatter in its value is reported in some alloy systems. The results of careful experiments in thin samples are analyzed to evaluate these systems and phase diagram parameters and their values are used in the application of theoretical model.

A set of experiments was also performed in thin samples over a range of compositions under different growth rate and thermal gradient conditions. These results are used for the selection of alloy composition and experimental matrix for the next set of experiments in DECLIC/DSI-R where the evolution of sidebranches in well-developed dendritic array will be investigated.

Flow boiling and condensation have been identified as two key mechanisms for heat transport that are vital for achieving weight and volume reduction as well as performance enhancement in future space systems. Since inertia driven flows are demanding on power usage, lower flows are desirable. However, in microgravity, lower flows are dominated by forces other than inertia (like the capillary force). It is of great interest to investigate limits of low flows beyond which the flow is inertial enough to be gravity independent. One of the objectives of the Flow Boiling and Condensation Flight Experiment is to investigate these limits for flow boiling and condensation.

A two-phase flow loop consisting of a Flow Boiling Module (FBM) and two Condensation Modules (CM) has been developed to experimentally study flow boiling condensation heat transfer in the reduced gravity environment provided by the reduced gravity platform. This effort supports the development of a flow boiling and condensation facility for the International Space Station (ISS). The closed loop test facility is designed to deliver the fluorocarbon test fluid to the inlet of any of the test modules at specified thermodynamic and flow conditions. The zero-g aircraft tests will provide subcooled and saturated flow boiling critical heat flux and flow condensation heat transfer data over a wide range of flow velocities. Additionally, these tests will verify the performance of all gravity sensitive components, such as evaporator, condenser and accumulator associated with the two-phase flow loop.

We will present in this paper the breadboard development and testing results which consist of detailed performance evaluation of the heater and condenser combination in reduced and normal gravity. We will also present the design of the reduced gravity aircraft rack and the results of the ground flow boiling heat transfer testing performed with the Flow Boiling Module that is designed to investigate flow boiling heat transfer and Critical Heat Flux (CHF) phenomena.


Thermal creep is one of the most common phenomena in rarefied gas dynamics generating bulk flows due to a non-uniform temperature along solid-gas interfaces. Its manifestation on macroscopic level is similar to a moving boundary at no-slip condition. It is getting especially important in microgravity experiments with dust clouds, where the gas pressure is typically below 1000 Pa. Thermal creep-induced convection may be a source of problems resulting in parasitic particle displacement or even in sweeping away of the cloud from the observation volume when the temperature on the chamber elements is not sufficiently uniform. On the contrary, when put under control, thermal creep may be used to create nearly arbitrary time-dependent three-dimensional flows, from being stationary uniform to temporally periodic saddle-type profiled in space. Such flow fields can provide cloud trapping and rapid growth of particle number density based on dynamic balancing of the Paul trap type [Paul, 1990]. These phenomena and techniques are of prime importance to the European Space Agency’s scientific program interactions in Cosmic and Atmospheric Particle Systems (ICAPS), planned to fly on the International Space Station [Blum et al., 2008] and aimed at increasing our knowledge about dust agglomeration in atmospheric processes, related to protoplanetary matter formation [Blum and Wurm, 2008]. Development of the core elements of the thermal-creep-flow generators was based on the use of specially designed thermoelectric elements creating local temperature gradients of higher than 100 K/mm and temperature variation rates of up to 500 K/s. Short duration microgravity experiments in the Bremen drop tower allowed verification of the concept and quantitative comparison with the model. Controlled uniform cloud displacement, formation of complex three-dimensional cloud patterns, rapid particle agglomeration, and growth of extended agglomerates was observed and studied.


[C27.3] Two Phase Flow Separator Experiment Utilizing Two Passive Separator Designs Aboard Parabolic Aircraft. L.M. Sharp, K.M. Gilkey, G. L. Chahine, Y. Kamotani, N. T. Pham, N. R. Hall, E.W. Goodwin. NASA Glenn Research Center, 21000 Brookpark Road, Cleveland, OH 44135, USA; 2Dynaflow Inc, 10621-J Iron Bridge Road, Jessup, MD 20794, USA; 3Case Western Reserve University, 10900 Euclid Avenue, Cleveland, OH 44106, USA.

The separation of multiphase flow constituents in a microgravity environment is of considerable interest as the functionality of many spacecraft systems is dependent on the proper sequestration of interpenetrating gas and liquid phases. Centrifugal separators provide the desired gas-liquid separatory action by swirling the multiphase flow – causing the gas to accumulate along the axis of the vortex as the denser liquid is forced to the walls – thereby allowing segregated extraction of the respective phases. Passive cyclonic separators utilize only the inertia of the incoming flow to accomplish this task.

The ultimate objective of this experiment is to facilitate the maturation of passive cyclonic separation technology through combined experimental, computational, and analytical analyses. These approaches are being employed in order to quantitatively assess and delimit the range of operability of a new separator design with respect to both transient and steady-state behavior at a device and system level – features that have yet to be completely explored in any such device.
The Two Phase Flow Separator Experiment (TPSFE) rig serves as a flow system that allows for the metering of liquid and vapor mixtures into an instrumented test section. For this microgravity flight, the test section consists of two different passive two-phase flow separators possessing tomographic, pressure, and conductance probe diagnostics.

Gas is supplied by a commercial cylinder and controlled via thermal mass flow controllers. Liquid is available as a closed-loop supply that is made motile by the presence of a piston in the water supply tank. The regulated compressed gas source provides the pressure with which to move the piston. The water and gas are brought together in a mixer and then directed to the test section in a two-phase flow development pipe. After separation in the test section, the respective gas and liquid outlets are brought together in the collection tank. The gas is exhausted to atmosphere through a backpressure regulator while the liquid remains in the tank to be pumped back into the supply tank in between tests.

A layer of liquid with a free surface will convect when heated from the liquid side. This convection is due to both buoyancy and surface tension driven gradients. We present an experimental and theoretical study that is concerned with the thermal temporal and spatial pattern development when a bilayer of liquid and gas are heated from the liquid side. What causes these oscillations? We think that the oscillations are seen when there is a competition that arises from surface tension gradients that normally causes flow upward into troughs and buoyancy that normally causes flow upward toward crests.

The results of this experiment are of importance on material processing of crystal growth. We will present the theory of convection and the nature and physics of the oscillations that are seen in the bilayer system.

Support from NSF OISE 0968313, SRI UCF01-0000265199 and NASA NNX11AC16G is gratefully acknowledged.

Concurrent Session 28: Physical Sciences

Overview, Informatics and KIBO Facilities

Session Co-Chairs: Fran Chiaramonte and Sharon Conover, NASA Headquarters

Time: Wednesday, 10:30 am – 12:00 pm

[C28.1] Space Physical Sciences in Canada. M. Dejmek. Canadian Space Agency, 6767 Airport Road, St-Hubert, Quebec, Canada, J3Y 8Y9.

Canadian researchers have continued to produce scientific innovation in the space physical sciences over the past year. This knowledge advances the nation’s understanding of gravity-driven industrial processes in material sciences and processing, fluid physics, combustion and flame research, protein crystal growth, and fundamental physics. Scientific research platforms include drop towers and parabolic aircraft, sounding rockets, recoverable satellites, and the International Space Station (ISS). This presentation will provide an outline of the Canadian scientific objectives for many physical and chemical processes under study, and summarize near free-fall scientific results over the past year. It will summarize the associated national and international space science missions involving Canadian researchers, as well as the scientific objectives and investigations conducted during the C2 Expedition (Research Increment 34/35) to the ISS which involved the first Canadian to command the orbiting laboratory in 2013. Supported by the Canadian Space Agency.

[C28.2] Japanese Research Facilities on ISS. M. Natsuisaka1, 1ISS Science Project Office, Institute of Space and Astronautical Science (ISAS), Japan Aerospace Exploration Agency (JAXA), 2-1-1 Sengen, Tsukuba, Ibaraki, JAPAN. Japan has been operating Japanese experiment module, KIBO, on ISS to perform physical, biological, medical, and space sciences in space. KIBO pressurized module currently accommodates two research racks for physical sciences, one research rack for life science and one research rack can be dedicated to the various research fields.

(1) RYUTAI (“fluid” in Japanese) rack: RYUTAI rack accommodates FPEF (Fluid Physics Experiment Facility), SCOF (Solution Crystallization Observation Facility), PCRF (Protein Crystallization Research Facility), and IPU (Image Processing Unit). FPEF is a research facility targeting precise observations on Marangoni convections in a liquid bridge. SCOF having versatile diagnostics is an in-situ observation facility for solution crystal growths. PCRF is a process unit to produce high quality protein crystals, which can be provided to a X-ray and/or neutron structural analysis. IPU can store imagery data from FPEF, SCOF and PCRF, convert those to appropriate data formats, and download those to ground via communication network on ISS.

(2) KOBAIRO (“gradient heating furnace” in Japanese) rack: GHF (Gradient Heating Furnace) having three heaters can achieve unique heating profiles to produce high quality semiconductor crystals.

(3) SAIBO (“cell” in Japanese) rack: SAIBO rack accommodates CBF (Cell Biology Experiment Facility) and CB (Clean Bench). CBF is an incubator to cultivate cells, seeds of plants, C.elegans etc. Since CBF has two chambers with/without a centrifuge rotor, the effects of gravity and/or space radiation can be distinguished from comparisons of the specimens grown in those. Since CB can work as a life science glove box having a fluorescence microscope, the cultivated specimens with CBF can be observed on orbit.

(4) Multi-Purpose Small payload Rack (MPSR): MPSR offers two parts of free volumes. Researchers can install their unique hardware into those and carry on their researches. Combustion Chamber and AQH (Aquatic Habitat) which are now on orbit as the inserts of MPSR individually execute combustion researches and keep “Medaka” on orbit. ELF (Electrostatic Levitation Furnace) and KIKUCHI KOSSEL (a diffraction meter for colloid crystals) which have been developed are also in the MPSR rack.

The presentation will also introduce scientific aspects of research projects using those facilities.

[C28.3] International cooperation in physical sciences research in space in the framework of ESA’s ELIPS programme. O. Minster, L. Cacciapuoti, A. Orr, B. Toth, D. Voss, Physical Sciences Unit, Utilisation and Astronaut Support Department, Human Spaceflight and Operations Directorate, European Space Agency.
ESA supports research and applications activities in physical sciences in the framework of its European Life and Physical sciences in Space (ELIPS) programme. Research projects are incubated in the context of International Topical Teams coordinated with other partner space agencies. This preparation phase concludes with the submission of team proposals to regular Announcements of Opportunity issued by the different agencies. The international research plan covers a broad range of topics in physics such as: *Fundamental physics (test constants of the Universe, mimic interactions), *Length and time scales in complex fluids (e.g. self-organisation of matter, soft matter dynamics), *Thermo-physical and -chemical properties measurements (e.g. diffusion and thermodiffusion, surface properties), *Fluid dynamics and phase changes and related instabilities (vibrational, thermocapillary or hydrochemical flows, heat transfer) with a strong interdisciplinary dimension to most topics. These programmes span over long periods of time and optimally use the various space platforms available to ESA. A large number of these projects will eventually use instruments on the International Space Station. Close coordination is sought with the other ISS partners such that instruments can be contributed by any of the ISS partners as deemed most efficient or complementarity of different instruments is fully exploited. The projects covered by this research cover basic and applied research, with in several cases, industries associated to the teams running these projects. This industry support has been sustained throughout the preparation for space experimentation such that relevant knowledge can be efficiently utilised. As any space technology development requires a solid scientific basis, initiatives are taken in anticipation of future technologies that will be required to implement future space exploration programmes. This element of the programme should not be seen as a change of emphasis in the current ESA ISS utilisation programme, but as the natural extension from a knowledge-acquisition phase to a practical utilisation phase.


NASA’s Physical Science Research Program has made contributions in two distinct areas: first, fundamental research, which is investigating physical phenomena in the absence of gravity and fundamental laws of the universe, and providing new knowledge of scientific value and societal benefit and second, applied research, which is contributing to the basic understanding underlying space exploration technologies such as power generation and storage, space propulsion, life support systems and environmental monitoring and control. Both have led to improved space systems or new products on Earth. The program also has benefited from research collaborations with several of the ISS international partners (Europe, Japan and Canada) and individual foreign governments with space programs, such as France, Germany and Italy. NASA’s physical science research is organized into six disciplines – biophysics, combustion science, complex fluids, fluid physics, fundamental physics and materials science. Conducted in a nearly weightless environment, experiments in these disciplines reveal how physical systems respond to the near absence of buoyancy-driven convection, sedimentation or sagging. They also reveal how other forces, such as capillary forces, which are small compared to gravity, can dominate the system behavior in space. Examples of observations in space include boiling in which bubbles do not rise, colloidal systems containing crystalline structures unlike any seen on Earth, circular flames burning around fuel droplets, directional solidification of metal alloys producing a uniformly aligned microstructure that improves material properties, and fluids rising in relatively wide channels without the use of a pump.

In the current ISS era, we now have an orbiting laboratory that provides the highly desired condition of long-duration microgravity. This allows continuous and interactive research similar to Earth-based laboratories, even providing statistical validity when required.

**[C28.5] Physical Science Informatics: Providing Open Source Access to ISS Science Data for the Benefit of All.** B.L. Henrie1, T.Y. Miller2, R.D. Green3, and F.P. Chiaramonte4. 1Dynetics Technical Services, Huntsville, AL, USA; 2NASA Marshall Space Flight Center, Huntsville, AL, USA; 3 NASA Glenn Research Center, Cleveland, OH, USA; 4NASA Headquarters, Washington DC, USA.

As more government agencies are making more data and information freely available online for researchers and the general public, NASA is pursuing development of an open source informatics system for the physical science ISS flight experiments to allow full access to the trove of data collected over the life of ISS, along with the on-going and future open source experiments. The goal is to provide global access to the data, thereby accelerating the time from ideas to publication and products. It will also fuel innovation and discovery and should lead to increased economic growth. Previously, a team at MSFC has developed series of informatics systems for several other applications, beginning with the Materials and Processes Technical Information System (MAPTIS), an informatics systems that provided detailed properties on a large database of materials used for spacecraft systems. Follow-on informatics systems include Satellite Contamination and Materials Outgassing Knowledgebase (SCMK). A new informatics system has been recently set-up for the MISSE (Materials International Space Station Experiment) series for materials exposed to the low Earth orbit environment and data is being loaded into MAPTIS as it becomes available. All three of these informatics systems were developed with the Athena platform, a software environment developed in-house by the MAPTIS team to incorporate large databases of science and engineering data and allows access in an open, organized manner. The Physical Science informatics system is the next step in this an effort to make NASA sponsored flight data available to the scientific and engineering community, along with the general public. The experimental data, from six overall disciplines: Biophysics, Combustion Science, Fluid Physics, Complex Fluids, Fundamental Physics, and Materials Science, will present some unique challenges. Besides data in textual or numerical format, large portions of both the raw and analyzed data for many of these experiments are digital images and video, requiring large data storage requirements. In addition, the accessible data will include experiment design and engineering data (including applicable drawings), any analytical or numerical models, publications, reports, and patents, and any commercial products developed as a result of the research.

Supported by International Space Station Physical Science Informatics System.
[C29.1] The Space Life Science Training Program at NASA Ames Research Center. P.E. Randazzo\textsuperscript{1,3}, J. Smith\textsuperscript{1}, S. Sun\textsuperscript{2}, and K. Gibbs\textsuperscript{3}.
\textsuperscript{1}Program Staffer, Lockheed-Martin Space Life Science Training Program, Space Biosciences Division, NASA Ames Research Center, \textsuperscript{2}Space Biosciences Research Branch, Space Biosciences Division, NASA Ames Research Center, \textsuperscript{3}Lockheed-Martin, NASA Ames Research Center.

NASA Ames Research Center (ARC) in the heart of California’s Silicon Valley is restarting the Space Life Sciences Training Program. NASA Ames and desires to keep the high academic intensity of the program and utilize completely the unique biology, astrobiology, and synthetic biology expertise at the center.

The major goal of SLSTP is to develop a cadre of qualified scientists and engineers to address future space life sciences research and engineering challenges. This is accomplished by assigning small groups of up to 3 students to work closely with Principle Investigators and completing tasks such as designing space flight experiments, studying launch and landing stresses, solving engineering problems, and/or conducting beta tests on current experiments in preparation of flight. These experiences provide them with the insight to experiment design and the difficulties of crafting, controlling, designing, and analyzing space bioscience experiments right up to space flight readiness. The students also attend lectures with a versatile topic range (from sub-orbital flight to extra-solar planets to bioregenerative green technologies to synthetic biology), attend tours of various Ames labs and facilities and present their work at the Space Biosciences Division student poster session and at the American Society for Gravitational and Space Research (ASGSR) conference.

The application process is competitive and approximately 10% of the applications are admitted into the program based on their merit, team work, and passion to study space life science. This 10 week program is an equal opportunity program and is open to all undergraduate students who maintain a 3.2/4.0 G.P.A. The students receive a stipend, travel reimbursement to and from the center, and housing accommodations. SLSTP is funded by the NASA Human Exploration and Operations Mission Directorate (HEOMD) Division of Space Life and Physical Sciences (SLPS). The Space Biology Project at Ames manages SLSTP and the program is administered and executed by Lockheed-Martin in collaboration with the Ames Space Biosciences Division. For more information contact Kristina Gibbs at: kristina.gibbs@nasa.gov.

[C29.2] Student Near-Space Biological Research Using a Weather Balloon Platform. B. Beck-Winchatz\textsuperscript{1}, J. Bramble\textsuperscript{2}, \textsuperscript{1}STEM Studies Department, \textsuperscript{2}Environmental Science and Studies Department, DePaul University, Chicago, IL, USA.

Weather balloon flights provide affordable access for secondary and post-secondary student research in near-space conditions. Typical flights last for 2.0-2.5 hours and reach altitudes of over 30 km. During these flights payloads are exposed to intense cosmic and ultraviolet radiation and temperatures below -60° C. The atmospheric pressure at maximum altitude is below 1 kPa, approximately equal to the average atmospheric pressure on the surface of Mars. Thus, weather balloon flights are an ideal platform for introducing students to biological science in space research, such as space radiation health risks and counter measures. For example, Students can use soda bottles as pressurized space capsules. To stabilize the temperatures they can insulate the bottles with a variety of materials or build electric heaters. Temperature, pressure, cosmic ray intensity and other variables can be monitored with off-the shelf data loggers or with microcontroller-based flight computers the students can build themselves. The vital signs of onboard organisms can be monitored with camcorders. We have conducted near-space biology experiments with middle school, high school and college students. Suitable organisms include plant seeds, pill bugs, crickets, cockroaches, Daphnia magna, and bacteria. For example, younger students can explore the impact of space flight on seed survival. Older students can design experiments to tease apart the effects of radiation, temperature and pressure on seed germination, pill bug survival or Daphnia reproduction. Here we will provide a brief overview of the weather balloon platform and discuss concrete examples of near space biology experiments.


In a typical undergraduate research experience within the physical sciences the student is often assigned a small portion of a more comprehensive endeavor. While they may complete their assigned portion of the project, the larger investigation is usually one that was active prior to the student’s arrival in the lab and will continue once the student has left. What we present here are the results, lessons, and experiences from a multidisciplinary, multi-campus, undergraduate microgravity research program. This unique experience requires a team of undergraduate students to go from the idea stage to final report writing in one year, the highlight of which is flying their own experiment on NASA’s reduced gravity aircraft. During the entire one year process the team is also conducting a vigorous outreach program designed to reach young people across the state of North Carolina. The research is conducted as part of NASA’s competitive Microgravity University experience under the Reduced Gravity Education Flight Program. In order to further enhance and broaden the team work aspect of our program the multi-campus collaboration has looked at this valuable research experience as a way to include students from other disciplines, tapping into the skills that non-technical students possess. Over the years we have incorporated students from the departments of Mass Communications, Business Administration, Exercise Science, and Education in addition to the more traditional hard sciences and engineering. Because of its unique features, we believe this program provides the student with a broader, more comprehensive, and more stimulating research experience than a traditional one.

This program supported by grants from the North Carolina Space Grant consortium and UNCP Research Initiative for Scientific Enhancement (RISE).
**CONCURRENT SESSIONS 29-33**

**THURSDAY, NOVEMBER 7, 2013 (9:00 AM – 10:00 AM)**

[C29.4] ** Bringing ISS to Students on Earth: Drop Studies of Capillary Flow.** D. P. Stocker1, A. Wollman2, N.R. Hall1, M. Weislogel1. 1 NASA Glenn Research Center, Cleveland, OH, USA; 2Portland State University, Portland, OR, USA.

Space station research can be made real for secondary students through opportunities where they can create and conduct their own experiments. While opportunities for such experiments on the International Space Station (ISS) are very limited, students can create analogs that are conducted in ground-based microgravity facilities. Through various programs, students and teachers have had the opportunity to conduct microgravity research using both research aircraft and drop facilities. In 2013, a joint educational program of NASA and Portland State University (PSU) was pilot tested with grade 6-12 students from across the United States. The new program links students to the ISS’ Capillary Flow Experiments and directly engages them in experiment conception, design, analysis, and reporting. The students designed their own capillary channels using freely available Computer Aided Design (CAD) software, where younger students had the assistance of adults for the CAD design. The test cells were fabricated using a computer-controlled laser cutter and were tested with a low-viscosity, quick-acting silicon oil in PSU’s 2.1-second drop tower. The video results revealing the microgravity capillary behavior were provided to the teams for their analysis and reporting of results. The program engages students in both technology and ISS research and can inspire them to pursue careers in technical fields.

**Concurrent Session 30: Invertebrates**

**Session Chair:** Jamie Foster, University of Florida

**Time:** Thursday, 9:00 am – 10:00 am


The mechanosensitive organ of balance, the statocyst, of the land snail Helix aspersa provides an invertebrate analog to study functional changes in the central nervous system (CNS) induced by radiation and altered gravity exposures in both orbital missions and ground experiments. The statocyst is similar to the inner ear otolith organs in vertebrate species, yet it is a more "simple" structure with 13 statoreceptors / side that can be readily accessed for individual manipulations. Our model offers the advantage of studying in the same animal (1) behavioral “negative gravitaxis” reaction directly correlated with CNS function, and (2) direct electrophysiological responses of vestibular hair cells.

In our study we subjected adult snails Helix aspersa to broad range of gamma rays (1-500 Gy). Gamma radiation exposures triggered significant decline in vestibular function as a result of CNS damage. We observed the prolonged latency of behavioral responses and reduced maximum tilt sensitivity (impulses/s per ° tilt) of recorded responses across all applied doses of radiation. The decrease in vestibular sensitivity developed over time reaching significance in a two-week period; an acute response was significant only in high doses, and some recovery was observed only in the lowest dose used (1Gy). Dose-response curves show nonlinearity due to relatively high effects of low doses of gamma radiation.

In animals exposed to 4-, 16-, 20- and 32-days of 2G centrifugations, we also found decreased vestibular sensitivity (significant after 16- and 32-day exposures). Snails were in excellent shape and exhibited normal behavior during centrifugation (feeding, crawling, mating), so low statocyst responses were likely confined to neurovestibular adaptation following the increased gravity load. The attempt to reverse the changes by allowing snails to readapt to normal gravity for a week after centrifugation was partially successful: responses increased, but did not reach control levels.

Currently we are using near threshold doses of gamma radiation in combination with hypergravity exposure. We began centrifugation of snails that were previously exposed to 1 and 5Gy doses of gamma rays. Our collected data will address an important question: are these two independent forces act in synergy in relation to CNS damage or not.

Supported by NASA Postdoctoral Program at Ames Research Center, administered by Oak Ridge Associated Universities.

[C30.2] **Acute Hypergravity Causes Altered Gene Expression, and Affects the Oxidative Stress Pathway in Drosophila.** Ravikumar Hosamani, and Sharmila Bhattacharya. Biomodel performance and behavior laboratory, space bioscience division, NASA Ames Research Center, Moffett field, CA, USA.

Oxidative stress occurs in normal physiological processes in biological organisms. The reactive oxygen species (ROS)-induced damage to cell macromolecules kept under check by the host antioxidant defense. However, under the influence of environmental conditions such as hypergravity, there might be unchecked oxidative stress processes that could lead to adverse impact on cell/organism function and health. In the present study, we explored the hypothesis that acute hypergravity can result in significant changes in gene expression related to oxidative stress pathways in the fruit fly, Drosophila melanogaster. Young, 2-3 days old adult female flies of both W+1118 (control line) and Indy302 (oxidative stress resistant mutant) were exposed to hypergravity (3G) for 60 and 120 min.

Post-hypergravity exposure, heads were isolated and gene expression studies were carried out using qrt-PCR. Antioxidant enzymes, thioredoxins, peroxiredoxins, thioreredoxin Peroxidase, and Foxo (a transcription factor) group of genes were analyzed. Interestingly, among W+1118 flies, thiorerdoxins and peroxiredoxin genes showed significant alterations at 60 min time point. This effect was further enhanced at 120 min. However, Indy302 flies showed no significant changes in thioreredoxins. But peroxiredoxins and thioreredoxin peroxidase set of genes were significantly changed at both the time points. Gene expression study revealed that, significantly more genes were altered in W+1118 flies in comparison to Indy302 after hypergravity exposure. At the same time, vulnerability of W+1118, and resistance by Indy302 flies to this environmental stressor indicates that acute hypergravity does induce physiologic stress in Drosophila.

Supported by NASA funded grant #NNH09ZTT003N/FSB09PROP-0022 to SB.

Stereotyped vascular patterning is a key, genetically responsive phylogenetic classifier in tissues of major transgenic model organisms flown in space that include the mouse retina, leaves of Arabidopsis thaliana, and wings of the fruit fly Drosophila melanogaster. Genetic and other physiological adaptations of vascular pattern to space environmental factors such as microgravity and light have not yet been systematically quantified, despite widespread recognition of their critical importance for terrestrial and microgravity applications. Using the NASA VESeq GENERation Analysis (VESGEN) software, we demonstrate that the mapping and quantification of genetically modified vascular patterns in the Drosophila wing provides new, useful information for this important model organism. Overexpression of the H-C2 construct of the Notch antagonist Hairless resulting from deletion of the binding domain to Suppressor of Hairless [Su(H)] results in a phenotypic series of increasingly abnormal ectopic veins that is mechanistically and morphologically similar to wildtype response to heat shock (Johannes and Preiss, Mech Dev 115:3-14 2002). By VESGEN analysis, the eight stereotyped wing veins remained quite constant from wildtype (total vessel length \( L \), 1511 px) to Class 5 H-C2, the most perturbed construct (\( L \), 1474 px). However, smaller ectopic veins increased in number from 1 in the wildtype to 18 in Class 5 H-C2; \( L \) increased from 23 px to 564 px. Previously perturbed vascular patterning in tissues mapped by VESGEN include mouse coronary vessels and intestine, juvenile and adult Arabidopsis leaves, the avian chorioallantoic membrane, and the human and mouse retina.

We propose that mapping adaptations of vascular patterning to microgravity and other environmental factors offers useful, innovative read-outs that necessarily integrate complex regulation by interacting signaling pathways. VESGEN analyses of vascular pattern can be used in conjunction with ISS laboratory capabilities such as the Light Microscopy Module (LMM) both for ISS Life Sciences experiments, and for ISS control experiments of Life Sciences satellite experiments.

Supported by NASA grant NNH09ZTT003N/FSB09BRO-0022 to SB and NASA Space Life and Physical Sciences Program for PW.


Microgravity has a profound impact on those microbes that associate with animal tissues. Most studies, however, have focused on microbes that form pathogenic associations with animals and there is a general lack of knowledge regarding the effects of microgravity on mutualistic bacteria. In this study, we examined the effects of modeled microgravity on bacteria-induced development in the mutualistic association between the bobtail squid Euprymna scolopes and its luminescent bacterium Vibrio fischeri. To simulate the microgravity environment we incubated both the host squid and symbiont in high aspect ratio vessels during the initiation and development of the symbiotic association. The bacteria colonized the host light organ (i.e., the site of the symbiosis) normally, indicating that microgravity did not impede the initiation of the symbiosis. However, there were significant changes in the normal developmental events that typically occur after bacterial colonization. The first microgravity-induced phenotype included a delay and overall suppression of the trafficking of host macrophages into the host light organ. The host immune cells normally respond within 2 h of inoculation with the bacterial symbiont, however, in simulated microgravity there was a 10 h delay in the appearance of host immune cells in the light organ and cell abundance was approximately half of that in gravity controls. Additionally, there was a dramatic increase in the onset of bacteria-induced apoptosis in the host light organ. This phenotypic change may be the result of increased sensitivity to the microbe-associated molecular pattern molecule lipopolysaccharide (LPS), as purified LPS caused elevated levels of apoptosis in the host light organ. There were also changes in gene expression in the symbiotic V. fischeri under simulated microgravity conditions. Specifically, there was a down-regulation of gene hfq, which encodes an RNA-binding protein known to regulate virulence factors in certain pathogens. Mutants defective in this gene were unable to trigger similar levels of bacterial apoptosis in the host animals under simulated microgravity conditions. Together, these results suggest that microgravity can alter normal developmental events that occur in animal-microbe mutualistic interactions.

Supported by NASA Florida Space Grant Consortium award UCF01-000232913 and the Florida Space Institute Space Research Initiative.

Concurrent Session 31: Fundamental Physics 3 – Dusty Plasmas (Part I)

Session Chair: John Goree, University of Iowa
Time: Thursday, 9:00 am – 10:00 am


Experiments with complex (or dusty) plasmas under microgravity conditions have been performed since almost two decades in parabolic flight campaigns, with sounding rockets (TEXUS), and onboard the MIR station and the ISS. The PK-4 facility will be operated in the European Columbus laboratory on the ISS. Its launch is scheduled for end of 2014. It will be the successor of the successful experiments PKE-Nefedov (2001 – 2005) and PK-3 Plus (2006 – 2013) operated in the Russian segment of the ISS in cooperation between the Max-Planck-Institute for Extraterrestrial Physics (Germany) and the Joint Institute for High Temperatures (Russia). In contrast to its precursors, in which the complex plasma was investigated using a RF discharge, a DC discharge is employed in PK-4. In the present talk a review of the PK-4 project, supported by the European Space Agency (ESA) and the German Centre for Aviation and Space Travel (DLR), will be given. Furthermore, selected experiments with PK-4 performed in parabolic flights will be discussed.

Supported by ESA and DLR (50 WM 1150).

In laboratory plasmas, micrometer sized particles sediment in the lower sheath of a capacitively-coupled radio-frequency (RF) discharge. Only there the electric field is large enough to levitate the negatively charged particles. To study phenomena in large, extended dust clouds, experiments were carried out on parabolic flights. Under microgravity conditions the dust particles fill the whole plasma except for a central void. In such a system dust-density waves (DDWs) are spontaneously excited if the dust density is sufficiently high and the neutral gas pressure sufficiently low. Depending on the discharge parameters and the amount of dust injected in the plasma, the wave field exhibits commensurable or incommensurable frequency clusters with commensurate or incommensurate frequencies. When clusters of commensurable frequencies, e.g., harmonics of a fundamental, are formed, a simultaneous modulation of the plasma glow is found. Measurements of the RF-amplitude and signals obtained from a Langmuir probe show, that the entire discharge is affected by the DDWs. Furthermore the plasma modulation has the same frequencies as the density waves. We therefore regard the discharge with the dust particles and the electric circuit as a self-organized system exhibiting the observed instability at certain parameters. In this contribution the findings will be discussed in detail.

Supported by the German aerospace agency (DLR) under grant No. 50WM1139.

[C31.3] Developments for the Proposed International Space Station Experiment “PlasmaLab.” U. Konopka, C. Knapec, G. Wildgruber, H.M. Thomas, M. Rubin-Zuzic, E. Thomas, B. R. Lynch, G.E. Morfill. 1Auburn University, Physics. Department, 206 Allison Laboratory, Auburn, Alabama 36849, USA; 2Max-Planck-Institute for extraterrestrial physics, P.O. Box 1312, 85741 Garching, Germany. The “PlasmaLab” is a proposed multi-user experiment facility, with international contributions, dedicated mainly to complex plasma research aboard the International Space Station (ISS). It is planned to be the successor of the ISS based experiments “PK-3Plus” (still operational, RF-discharge) and “PK4” (to be launched soon, DC-discharge). To be able to fulfill the requirements of a multi-user facility and to strongly extend the accessible complex plasma parameter space, new plasma chambers were developed as part of a DLR (German Aerospace Center) financed project. Two different kind of plasma chambers were identified as possible core device for “PlasmaLab”, one of cylindrical and one of spherical-like geometry. Both chambers have their own, unique features that open up the possibility for investigations on a variety of common as well as disjunctive problems. So far, we focused our development towards the cylindrical discharge chamber which, beside supporting a bigger plasma volume than earlier experiment, also incorporates several design features that allow for advanced plasma manipulations. We have also started developing new/enhanced techniques for analyzing the expected experimental data. The status of the development and selected results that demonstrate some of the new features of the experiment setups will be presented.

The project “Development of Plasma Chambers for the Investigation of Complex Plasmas under Microgravity Conditions aboard the ISS-PlasmaLab” is funded by DLR under contract 50WM0700.

Concurrent Session 32: Biophysics 2
Session Chair: Brian Motil, NASA Glenn Research Center
Time: Thursday, 9:00 am – 10:00 am


The marriage of physical and biological systems will be necessary as we move deeper into space. Many investigations have been performed across the many disciplines that will be included in the integrated sustainable life support system. In all cases this system will be tasked with providing conditions that support human life in a highly reliable manner adapting to various operating conditions. Ideally, the transit vehicle and planetary habitat systems in their final, autonomous configuration should only have one waste product, heat. All other elements of the system need to be conserved, recycled, and offset with local (in situ) resources. The transition from where we are today to this end state is where bioregenerative systems and biological engineering will play a key role as it becomes part of the physical chemical systems currently in use. The development of living systems that can support the needs of exploration and habitation outside the earth system is the primary task. Clearly humans are central to this living system but other living organisms will be in the system adding to its complexity and diversity. The system must support all elements in harmony. Working backward from this end state defines the critical path required to enable future sustainable life support systems that approach self-sufficiency.

Concurrent Session 33: Combustion 1 – Droplet Combustion Session I
Session Chair: Michael Hicks, NASA Glenn Research Center
Time: Thursday, 9:00 am – 10:00 am

[C33.1] A Ground-based Research for Fuel Droplet Cloud Combustion Experiment “Group Combustion” on KIBO/ISS. M. Mikami, T. Seo, H. Nomura, O. Moriué, M. Kikuchi, D.L. Dietrich. Yamaguchi University, Japan; Nihon University, Japan; Kyushu University, Japan; JAXA, Japan; NASA GRCC, USA.

A Japan-U.S. joint research on combustion experiment titled “Elucidation of Flame Spread and Group Combustion Excitation Mechanism of Randomly-distributed Droplet Clouds (Group Combustion)” is being prepared for space experiment on the Japanese Experimental Module “KIBO” in ISS. The purposes of this experiment are to verify the flame-spread hypotheses, which are based on the percolation theory and the findings from ground-based microgravity experiments on flame spread of fuel droplet arrays and to develop a percolation model which well describes the group combustion excitation in fuel droplet cloud through the flame spread.

Percolation theory predicts that a transition occurs at the critical droplet-number density between partial combustion and group...
combustion of fuel sprays in flame spreading over randomly-distributed droplet clouds. This transition is possibly identical to the transition between incomplete combustion and stabilized combustion in practical combustors. Application of Percolation theory to flame spread of droplet clouds requires information on the flame spread between droplets. In the present space experiments, the droplets are arranged on cross points of 14-micron-SiC fiber lattice (30x30) by using a three-dimensional traverse system to produce droplet cloud elements and randomly distributed droplet cloud. The flame and droplet positions and temperature distribution are measured during the flame spread over the droplets. We investigate the effect of droplet interaction and free droplet on flame spread in a scale of droplet size order and effect of radiation heat loss, which becomes important in flame spread from a group flame to another droplet cloud.

We have conducted ground-based researches for the space experiment “Group Combustion”, some of which are microgravity experiments on flame-spread of fuel-droplet-cloud element with uneven droplet spacing using a drop experiment facility. Flame spread to a droplet followed by burning with two-droplet interaction was observed to investigate the effect of flame-spread direction and local interactive effect. We demonstrated temperature measurement around burning droplets by Thin Fiber Pyrometry (TFP) method based on visible radiation from SiC fibers suspending droplets and proved that this method can capture transient features of thermal layer developing around burning droplets and detect ignition of droplets.

[C33.2] ISS Droplet Combustion Experiments - Uncertainties in Droplet Sizes and Burning Rates. Fei Yu and Benjamin D. Shaw. 1Computer Science Department, 2Mechanical and Aerospace Engineering Department, University of California, Davis, CA, USA.

Uncertainties in droplet size measurements and burning rates are evaluated for droplet combustion experiments that have been performed on the International Space Station. The focus of the present analyses is on non-sooting or lightly sooting droplets. Random and systematic errors are considered and different approaches for image and data analysis are investigated. Backlit droplet images generally show evidence of interference at the droplet edge via the appearance of a bright ring. The influences of diffraction, interference, and partial coherence on droplet images are considered via Fourier optics modeling. It is found that light diffraction at the droplet edge as well as camera discretization can contribute significantly to the droplet size and burning-rate uncertainties. Other error sources include background light variations and partial coherence effects. Ninety-five percent uncertainties in droplet diameters and burning rates are typically in the ranges ±0.05 mm to ±0.1 mm and ±0.02 mm²/s to ±0.04 mm²/s for the specific experiments that were analyzed. It is noted, however, that uncertainties can be significantly larger during ignition and also shortly after ignition.

Supported by NASA through grant NNX11AC66G. The Technical Monitor was Dr. Daniel L. Dietrich.


The ICE-GA (Italian Combustion Experiment for Green Air), as follow-on to the FLEX (FLame EXtinguishment) experiments, has the objective of studying the combustion of binary mixtures, emulating real fuels rich in renewable green components, in microgravity conditions. To this aim, droplets composed of n-heptane/ethanol and n-decane/1-hexanol will be studied by using the Combustion Integrated Rack (CIR) and the associated Multi-user Droplet Combustion Apparatus (MDCA) that is currently in-orbit aboard the International Space Station (ISS). The experiment will investigate the combustion of fiber supported droplets ranging from 1mm to 4 mm at different pressures and oxygen concentration. The pressure will be varied from below atmospheric pressure to 0.3 MPa. The experimentation will be carried out in synthetic atmosphere whose composition will be changed from oxygen-rich conditions down to flammability limit.

n-decane and n-heptane are two alkane fuels with high sooting tendency. The low sooting tendency of the alcohols will lighten the soot shell formed around droplet by the combustion of n-alkane fuels. This should facilitate the study of the burning of droplets formed with the mixture. The analysis of the reduction of the droplet diameter permits also the study of the non-ideal behaviour of the mixture.

n-decane and n-heptane represent good surrogates of aviation fuels and diesel fuels, respectively. Thus it is of particular interest to study their heating, vaporization and combustion when mixed with high concentrations of bio-alcohols. Both ethanol and hexanol can be in fact considered as drop-in-fuels derived from non-food biomasses (cellulose, hemicellulose, lignin, etc.) by means third but also fourth generation transformation processes.

The FLEX-ICE-GA experiment will provide systematic experimental data on the interaction of sooting and non-sooting fuels in the combustion of an equal binary mixture of the two. The data from the experiments include details of the droplet diameter, flame dynamics from both OH* chemiluminescence and standard color images and also soot and flame temperatures. The paper will report the first analysis of the experimental data acquired during the testing campaign carried out on the ISS during the expeditions 35/36 and 37/38.
[C34.1] Operations of an experiment on plant tropisms on the International Space Station (Seedling Growth-1). J.Z. Kiss¹, K.D.L. Millar², R.E. Edelmann². ¹Dept. Biology & Graduate School, University of Mississippi, Oxford, MS, USA; ²Dept. Botany, Miami Univ., Oxford, OH, USA.

The new Seedling Growth project on the International Space Station (ISS) builds on our previous spaceflight and ground-based experiments by using the model plant Arabidopsis thaliana to study the interactions between phototropism and gravitropism in plant development. Seedling Growth-1 was successfully launched on the Space X-2 mission to the ISS in March 2013. Four runs of the experiment in the European Modular Cultivation System (EMCS) were performed on the ISS during the period from March to May 2013. The data from these experiments included video downlinks of the seedlings to analyze growth, development, and tropistic curvature at various light and gravity treatments (made possible by the variable speed centrifuge on the EMCS). Samples were frozen in the -80°C MELFI freezer and will be returned to Earth in the GLACIER freezer on a future Space X mission. In this presentation, we will discuss the operational challenges and successes of Seedling Growth-1. In addition, several improvements in the experiments compared (to the previous TROPI experiments) included infra-red imaging of the seedlings and a novel strategy to mitigate light leaks between the rotors on the EMCS. Preliminary results on blue-light-based and red-light-based phototropism at a range of gravity levels from microgravity to fractional gravity to the 1-g control will be presented. Due to our interest in reduced gravity as on the Moon and Mars, this project is relevant to the long-term exploration agenda proposed by international space agencies. Supported by NASA grant NNX12AO65G.


Plants constantly align their growth axes parallel to the gravity vector. The sensing and response to changing gravity vector affects genes. We examined these changes in Brassica rapa roots that were reoriented and clinorotated. Gene expression levels related to the actin cytoskeleton (ACT7 and ADK1) and auxin transport (PIN1, PIN3, AGR1, ARG1) were assessed in B. rapa roots grown for 42 hours and then reoriented to 90° for 1, 2, and 4 hours or imbibed and clinorotated vertically or horizontally for 42 hrs at 1 rpm. After treatment, roots from 25 seedlings were cut into three sections, the root cap, elongation zone, and maturation zone, combined and used as one sample. RNA was extracted and reverse transcribed and analyzed by quantitative PCR. The results show that gene expression fluctuates in response to duration of reorientation and direction of clinorotation. Expression also varies along the length of the root; however, these changes are gene specific. Because of the variability of the expression profile, analyses that are based on the entire root miss important and tissue-specific changes in gene expression. Supported by NASA grant NNX10AP91G and LaSPACE GSRA.

[C34.3] Differential Signal Expression of Arabidopsis GFP Reporter Gene Constructs on Orbit. E.R. Schultz², A-L Paul¹, and R.J. Feri¹. ¹Program in Plant Molecular and Cellular Biology; ²Horticultural Sciences Department; ³Interdisciplinary Center for Biotechnology Research, University of Florida, Gainesville, Florida 32610 USA.

Green fluorescent protein (GFP) is commonly used as a reporter gene in many applications of biology. Traditionally, experiments have looked at redistribution of the signal, along with its appearance or disappearance among the conditions tested. In this experiment, average GFP intensity of two reporter genes was quantified in Arabidopsis seedlings over time in spaceflight (and in the comparable ground control) to address the spaceflight influence on auxin signaling.

Dormant Arabidopsis seeds were flown on STS-130, activated, and grown from 21 February 2010 to 7 March 2010. Plants were grown on phytagel plates on the GFP Imaging System (GIS) within the Advanced Biological Research System (ABRS) on the International Space Station (ISS). White light and fluorescent images were taken every 6 hours for 14 days. Images were imported into ImageJ for analysis. Green pixel intensity was measured using a constant line trace across hypocotyls. In order to identify the hypocotyl from the background, green maxima were selected following the color profile plot generated by ImageJ. Data were normalized, plotted by signal intensity vs. time, with error bars calculated as standard error of the mean.

The reporter gene lines tested were Adh::GFP (alcohol dehydrogenase; an indicator of hypoxic stress response), DRS5::GFP (a synthetic promoter composed of five auxin-response elements). The Adh::GFP lines showed no significant difference in reporter gene expression levels between ground control and spaceflight. The DRS5::GFP lines grown on the ISS initially had lower levels of reporter gene expression when compared to ground controls; however, at about day 10, the levels of DRS5::GFP expression in the spaceflight plants began to increase, and then surpassed that of the ground controls.

The difference in DRS5::GFP expression between spaceflight and ground control plants implies an underlying auxin-mediated response to the spaceflight environment. GFP signal quantification can help reveal subtle differences in transcriptional activity associated with that response. Assuming the brightness of a signal correlates with the amount of GFP in that area, higher signal intensities indicate active regions of auxin-mediated gene expression in a tissue-specific manner.

This work was supported by NASA grants NNX09AL96G, NNX07AH270 and NNX12AN69G to RJF and A-L Paul.

[C34.4] Effect of Atmospheric Pressure on Wet Bulb Depression. R.M. Wheeler¹, M.S. Stasiak¹, J. Lawson², C.A.P. Wehkamp², and M.A. Dixon². ¹NASA Kennedy Space Center, FL, USA; ²School of Environmental Sciences, University of Guelph, ON, Canada.

Future human exploration missions in space would likely use vehicles with lower cabin pressures. A target pressure often mentioned is 8 psi (55 kPa). With appropriate O₂ partial pressures, this would allow rapid egress using space suits (e.g., no “breathing”), and could reduce overall gas leakage from the vehicle. Pressure fundamentally affects many physical and thermodynamic properties of the air, including psychrometric parameters. We were interested in the effects of pressure on water evaporation and wet
bulp depression, and how these might relate to growing plants at reduced pressures. Theoretical models for pressure effects on wet bulb depression and adiabatic saturation pressure have been published (e.g., Shallcross, 1997), but to our knowledge, none of these have been tested empirically. We placed a large wet/dry bulb psychrometer in a hypobaric chamber and measured wet bulb temperatures at 10, 20, 50, 80 and 98 kPa total pressure, while maintaining the chambers at 30, 50, and 70% relative humidity (note, RH and saturation pressure for water vapor are essentially independent of pressure). The results showed a close match with theoretical predictions of wet bulb depression and adiabatic saturation pressures. As pressures dropped, wet bulb depression increased for a given relative humidity. The findings support the frequently observed increase in plant transpiration rates at reduced pressures, and suggest that increased water evaporation rates and associated cooling of evaporative surfaces can be expected at reduced atmospheric pressures. The issue of plant adaptation to hypobaria needs further study; there are indications that such adaptation mitigates increased gas exchange and water vapor loss by maintaining critical water status thresholds in plants.

[C34.5] A Short Interval Hypergravity Exposure Affects Photosynthetic and Biochemical Indices in Wheat. Pandit B. Vidyasagar, Sagar S. Jagtap, Jyotsana Dixit and Shailendra M. Kamble. Biophysics laboratory, Department of Physics, University of Pune, Pune -411007, MH, INDIA.

In the present study, changes in photosynthetic performance, chlorophyll a fluorescence and biochemical indices in response to short interval post imbibition hypergravity exposure were evaluated in wheat (Triticum aestivum var. Lok-1).

Imbibed wheat seed were exposed to hypergravity ranging from 500g to 2500 g for 10 min and allowed to germinate and grown for 5 days. Photosynthetic and biochemical analysis were carried out on 5th day. Chlorophyll a fluorescence transient were examined in wheat seedling raised from hyper gravity treated seeds. Fv/Fm, PI, Fv/ Fo decreased in hypergravity treated seeds compared with control. Photosynthetic performance indices such as Transpiration rate, Stomatal conductance, Net photosynthetic rate, intracellular CO2 concentration, intrinsic water use efficiency also declined wth hypergravity exposure in wheat seedlings raised from hyper gravity treated seeds. This suggests that exposure to high g results in reduced efficiency of photosynthesis in wheat seedlings. Results of Biochemical analysis showed reduced alpha amylase activity in wheat seeds subjected to hyper gravity ranging from 500g to 2500 g in a magnitude dependent manner .This decline in enzyme activity was correlated with increased level of starch content and lower sugars content in hyper gravity exposed wheat seeds. These results possibly indicate that hyper gravity of 500 g and above inhibits alpha amylase induction from metabolically active aleurone layer in wheat seeds. Thus, possibly explaining reduced per cent germination and growth in hyper gravity treated seeds over the control. Moreover, antioxidant enzyme activity (CAT and POD) significantly increased as a result of hypergravity exposure over control. In conclusion, short interval hypergravity exposure results in reduced growth and photosynthetic activity in wheat seedlings.

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Concurrent Session 35: Vertebrates 3

Session Chair: Ruth Globus, NASA Ames Research Center

Time: Thursday, 10:30 am – 12:00 pm

[C35.1] Comparison between Botulinum Toxin-Induced Muscle Paralysis and Hindlimb Unloading as Disuse Models. R. Ellman1,2, D. J. Grasso1, M. van Vliet1, D. J. Brooks1, J. M. Spatz1,2, C. Conlon3, M. L. Boussein1,3. 1Center for Advanced Orthopaedic Studies, Beth Israel Deaconess Medical Center and Harvard Medical School, Boston, MA, USA; 2Health Sciences and Technology, Massachusetts Institute of Technology, Cambridge, MA, USA; 3Department of Orthopedic Surgery, Harvard Medical School, Boston, MA.

Bone receives mechanical stimulation from two primary sources, muscle contractions and external gravitational loading, but the relative contribution of each to bone maintenance is not well studied. Thus, we investigated the relative effects of paralysis and unloading on changes in muscle mass, bone mass and microarchitecture.

Adult female C57Bl/6J mice (12 wks old) underwent one of the following (n=10/group): botulinum toxin A (BTX) injection, hindlimb unloading (HLU), both HLU and BTX (HLU+BTX), or no intervention. BTX-treated groups received a unilateral IM injection to the quadriceps and calf muscle groups (2U/100g total dose) three days before HLU; all mice were sacrificed after 21 days. HLU, BTX and HLU+BTX all led to significant loss of leg muscle mass, hindlimb BMD and bone microarchitecture relative to controls, while generally the combined HLU+BTX intervention had the most detrimental changes in bone and muscle. As an example, controls gained BMD (+4.6%, p<0.001 vs. baseline) while HLU mice lost BMD (-4.9%, p<0.01). BTX-treated mice lost even more BMD in their injected leg (-19.1%, p<0.001), and the most severely affected were the HLU+BTX group with a -30.2% loss of BMD in their injected leg (p<0.001)— or 6-fold more than with HLU alone. Unexpectedly, we found a strong systemic effect of BTX affecting the un.injected (contralateral) leg that led to large BMD losses (-5.2% and -17.8% for BTX and HLU+BTX, respectively, p<0.05) and significant deficits relative to untreated controls in muscle mass (-25.2% BTX vs. control; -30.3% HLU+BTX vs. HLU) and trabecular bone volume (-24.0%, BTX vs. control; -52.8% HLU+BTX vs. HLU). The magnitude of this indirect effect was comparable to the direct effects of BTX treatment and HLU alone. This confounding factor hinders our ability to conclude whether muscle forces or external gravitational forces contribute more to bone maintenance, but it appears that BTX-induced muscle paralysis was more detrimental to muscle and bone than hindlimb unloading. In light of this, untreated controls should be included in future BTX studies to gauge the presence of indirect. Our data indicate that BTX may affect bone through mechanisms other than direct loading.

This work was funded in part by NIH R21 AR057522, NASA NNX10AE93G, and the National Space Biomedical Research Institute through NASA NCC 9-58. RE was supported by a NASA-Jenkins Pre-doctoral fellowship.

[C35.2] Changes in Mice Calvaria Following Fifteen Days in Space. R. Bhattacharya1, R.M. Healey2, E. Cory1, B. Zhang1, B.R. Macias1, R.L. Sah1, A.R. Hargens1. 1Department of Orthopedic Surgery, 2Department of Bioengineering, University of California San Diego, La Jolla, CA, USA.
Physiological changes due to microgravity are some of the main concerns to be taken into account prior to a space mission. Bone remodeling may occur in spaceflight as a response to unloading of the lower limbs and head-ward fluid shifts. While unloading results in significant loss of bone mass and density in the lower limbs of animals exposed to microgravity, increased fluid flow to the head may elicit the opposite effect. In bones that normally do not bear weight such as the skull, it is hypothesized that adaptation to microgravity can induce growth. This study discusses the various physiological effects of microgravity on astronauts and new data on remodeling of the skull in space. Seven 23-week-old female C57BL/6 mice representing the spaceflight group (n=7) experienced fifteen days of microgravity aboard the NASA shuttle mission STS-131. Eight female C57BL/6 mice, littermates of the spaceflight group, were maintained on land under normal gravitational loads and represent the control group (n=8). The spaceflight mice were euthanized within 3 hours after landing, and characteristics of their calvaria and those of ground controls were evaluated by micro-computed tomography (micro-CT) and biomechanical analysis. Micro-CT analysis indicated a significantly greater bone volume ratio in the spaceflight group, 1.904 ± 0.842 mm³, compared to 1.758 ± 0.122 mm³ for that of the control group (p<0.05). Likely due to the short duration of spaceflight, there was no significant difference observed in the other parameters, cortical thickness and tissue mineral density. Micro-indentation was conducted on the calvaria to determine mechanical stiffness. Taken over several consistent points on each specimen, the elastic modulus in the spaceflight group was significantly greater, 10.5 ± 1.9 GPa, compared to 9.3 ± 2.1 GPa in the control group (p<0.05). The differences observed in bone volume and stiffness infer that exposure to microgravity causes adaptive growth in calvarial bone.

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[C35.3] Effect of Myostatin Inhibition and Microgravity on LS Lumbar Vertebrae Trabecular Bone Microarchitecture in Mice. Stefanie M. Gonzalez, Alicia M. Ortega, Eric W. Livingston, Eric Jiao, Xiaoan Zhou, John Lu, Louis S. Stodieck, Ted A. Bateman, H.Q. Han, Virginia L. Ferguson. 1Department of Aerospace Engineering Sciences, Bioastronautics University of Colorado Boulder, 2Department of Mechanical Engineering, University of Colorado Boulder, 3Department of Biomedical Engineering, University of North Carolina-Chapel Hill, 4Amgen Inc., One Amgen Center Dr., Thousand Oaks, CA, USA. Musculoskeletal degeneration is a major concern during long duration spaceflight missions due to loss of 1-2% average bone mineral density per month and about 30% loss in the isokinetic strength in muscles. Previous studies have examined countermeasures based on modifying the factors that directly affect bone formation/resorption. However, a countermeasure that prevents both muscle and bone degeneration has not been well established. Thus, a genetically engineered decoy myostatin inhibitor (MI, a negative regulator of skeletal muscle) may protect against muscle atrophy and bone loss. To study the combined effects of MI in microgravity, the microarchitecture of trabecular bone in the L5 lumbar vertebrae of 9-week old female C57BL/6N mice was studied. Mice were flown on STS-118 for 12.7 days and were divided into four groups: ground vehicle (GV, n=12), ground drug (GD, n=12), flight vehicle (FV, n=11), and flight drug (FD, n=11). Micro-computed tomography was used to quantify properties of bone volume fraction (BV/TV), trabecular thickness (Tb.Th), trabecular separation (Tb.Sp), trabecular number (Tb.N), and connectivity density (Conn.Den); differences between groups were tested using 2-way ANOVA followed by a Tukey post-hoc test. Spaceflight (GV vs. FV) significantly decreased BV/TV (-13.9%) and Tb.Th (-10.0%), with no measureable change in Tb.Sp. In contrast, MI treatment significantly increased BV/TV (+18.2%) and Tb. Th. (+9.9%) (for FV vs. FD), with no significant change in Tb.Sp. On ground MI also significantly increased BV/TV, Tb.Th, and Tb.Sp by +14.1%, +7.3%, and +5.9% respectively (GV vs. GD). Tb.N and Conn.D remained unchanged with spaceflight or MI (ground or SF). MI treatment mitigated SF-induced bone loss, where measures of trabecular microarchitecture negatively impacted by SF remained at GV levels in the FD mice. Collectively, these data reveal the effectiveness of the myostatin inhibitor in mitigating deleterious effects of spaceflight on bone microarchitecture. Thus, MI should be explored as a potential countermeasure to maintain skeletal structure and prevent muscle degeneration during long duration space missions.

Ferguson lab would like to acknowledge National Aeronautics and Space and Aeronautics (NASA); Amgen Inc.; NASA Space Product Development (Cooperative Agreement NNC8-242); BioServe Space Technologies; the NASA Ames Research Center and Kennedy Space Center; and Andrea Hanson.

[C35.4] Sex and Gender are Not Lost in Space. Graham B.I. Scott, Saralyn Mark, Dorit B. Donoviel, Lauren B. Leveton, John B. Charles, and Bette Siegel. 1National Space Biomedical Research Institute, (NSBRI), BioScience Research Collaborative, 6500 Main Street, Suite 910, Houston ,TX 77030-1402; 2Center for Space Medicine, Baylor College of Medicine, BioScience Research Collaborative, 6500 Main Street, Suite 910, Houston, TX 77030-1402; 3Department of Molecular and Cellular Biology, Baylor College of Medicine, One Baylor Plaza, Houston, Texas 77030-1402; 4NASA Headquarters, 300 E Street SW, Washington DC 20024-3210; 5Department of Pharmacology, Baylor College of Medicine, One Baylor Plaza, Houston, Texas 77030-1402; 6NASA Lyndon B. Johnson Space Center, 2101 NASA Parkway, Mail Code SA, Houston Texas 77058.

The terms “sex” and “gender” actually have distinctly different meanings. “Sex” hinges on an individual’s genetic make-up, (i.e. XX is female and XY is male) and “gender” refers to a person’s self-identification as male or female based upon social constructs and interactions. Certainly, “sex” significantly influences health on Earth as well as in space, and serves as the foundation for personalized medicine. Despite the fact that only ~500 astronauts have flown in space to date, we have datasets suggesting that men and women respond somewhat differently to the spaceflight environment. Indeed individual astronauts experience profoundly personal responses as a result of six months of microgravity, space radiation and close confinement – however generalizable differences are also observed between the sexes.
During the first half of 2013, data from space and ground-based studies and observations on the impact of sex and gender-based health during spaceflight and on terra firma were analyzed by six work groups in the following areas: cardiovascular, musculoskeletal, neuro-vestibular, reproductive, immunological and behavioral. NASA and NSBRI recently showcased the results of this important research review via a virtual workshop (http://connect.arc.nasa.gov/p5wok9171zu/). In this presentation the key findings of all six Sex and Gender work groups will be discussed, along with recommendations for human health research priorities that are critical for the success of present and future spaceflight missions.

GS and DD supported by NSBRI through NASA NCC 9-58. SM, LL, JC and BS supported by NASA.

Concurrent Session 36: Fluid Physics 9
Session Chair: Steven H. Collicott, Purdue University
Time: Thursday, 10:30 am – 12:00 pm

[C36.1] The Capillary Channel Flow (CCF) experiments on the International Space Station. M. E. Dreyer, M.M. Bronowicki, P. Canfield, Center for Applied Space Technology, Department of Fluid Mechanics, Faculty Production Engineering – Mechanical and chemical engineering, University of Bremen, Bremen, Germany.

Due to the reduced importance of gravitational forces in low Bond number flows, capillary forces play a much more dominant role in fluid mechanics in environments with reduced gravity. This makes capillary channels an efficient method of liquid management in space, because they utilize capillary pressure to transport and position liquids instead of having to rely on pumps or other moving parts. One of the application areas of capillary channels is within liquid management systems where capillary forces are used to acquire liquid and preserve a continuous, bubble-free path between two specific points, e.g. within a tank between the liquid pool and an outlet. Previous studies have already shown that open capillary channel flows are subject to stability limits that depend on the channel’s geometry, the liquid’s physical properties, and the flow rate. In steady flow, the free surface, i.e. the gas-liquid interface, of the capillary channel flow collapses at a critical flow rate ingesting gas from the environment into the liquid. This instability of the interface depends on the properties of the liquid, the geometry of the channel and the magnitude of the flow rate. In 2011, open capillary channel flow experiments were conducted in the Microgravity Science Glovebox onboard the International Space Station. The CCF project is a joint German (DLR – ZARM) and American (NASA – PSU) endeavor. The experiment hardware was transported to the ISS onboard flight STS-131 of the space shuttle Discovery in April 2010. The hardware was controlled via telescience from ground stations in Bremen, Germany, and in Portland, Oregon. The experiments were performed on open capillary channels with different cross section shapes and the stability limits of steady and accelerated single phase flow were determined for various channel lengths. The experiments also included studies on the effects of two phase flow on the stability of the free surface of a capillary channel and on the feasibility of passive phase separation in an open tapered capillary channel. The results of the experiments are being used to help validate computer simulations and to improve the existing models. We acknowledge the support by DLR and NASA.

[C36.2] Future ESA experiments in Heat and Mass Transfer Research on-board the International Space Station. O. Minster¹, and B. Tóth². ¹European Space Agency; ²HE Space Operations for the European Space Agency.

On behalf of the international science team, and the project development and operations teams. The aim of the present contribution is to highlight the gas-liquid phase change heat transfer and related experiment candidates, within the frameworks of the European Programme for Life and Physical Sciences in Space (ELIPS), targeting the International Space Station (ISS). All of these experiments are planned to be conducted in the Fluid Science Laboratory of the Columbus module of the ISS. Evaporation Patterns (historically: CIMEX) aims at studying evaporation induced convection and associated gas-liquid interface phenomena. Under ESA contract, a consortium led by EADS Astrium is responsible for the hardware development activities. The current concept features a liquid pool evaporator, where thermocapillary convection is triggered at a planar gas-liquid interface. The diagnostics include thermal sensors, Infrared thermography, Schlieren visualisation and tomographic Interferometry. The parameters of the experiment include the thermal boundary conditions, the evaporator pool depth, the liquid composition and the circulation properties (flow rate and non-condensable gas content) of the gas-phase. The Multiscale Boiling (historically: RUBI) experiment aims at studying the fundamentals of pool boiling by analysing the behaviour of a single vapour bubble. The hardware is under development by EADS Astrium under ESA contract. The vapour bubble is generated on a sputtered heater. The growth of the bubble can be observed with a high-speed camera from the side and a retractable rack of microthermocouples to be able to assess macro-scale properties. Micro-scale phenomena at the three-phase contact line can be analysed through infrared acquisitions from the bottom side of the heater. A unique feature of RUBI is the possibility to study the effect of field forces on the vapour bubble: an electric field, and shear flow.

As the name of Thermal Platform 1 suggests, this experiment container is intended to serve a wider variety of studies. The hardware feasibility was studied under ESA contract by QinetiQ Space and EADS Astrium. Potential candidates include heat pipes, evaporation, condensation and boiling type of experiments, with particular emphasis on wettability aspects.

Concurrent Session 37: Fundamental Physics 4 – Cold Atom Laboratory (CAL)
Session Chair: Mark C. Lee, NASA Headquarters
Time: Thursday, 10:30 am – 12:00 pm

[C37.1] Interferometry with chip based atom lasers. E.M. Rasel for the QUANTUS cooperation. QUEST, Institut für Quantenoptik, Leibniz Universität, Germany.

We report on the implementation of a Bragg-type interferometer operated with a chip-based atom laser for Rubidium ⁸⁷Rb. With the chip based atom laser we can generate thermal ensemble as well as Bose-Einstein condensates (BEC). With the help of delta kick cooling,
implemented via the atom chip, we can further slow down the expansion of thermal and condensed atoms. In addition, the chip allows to transfer atoms in the individual Zeeman states of the two Hyperfine groundstates, in particular into the non-magnetic state. With this toolbox we could extend the observation of a BEC of only 10,000 atoms to macroscopic time scales approaching two seconds. Benefiting from the extended free fall in microgravity we could combine this with an asymmetric Mach-Zehnder type interferometer over hundreds of milliseconds to study the coherence and to analyse the delta kick cooling with the help of the observed interference fringes. This experiment can be considered as a double slit experiment in microgravity. A novel generation of atom chips allows to improve the performance of these flexible devices. We could demonstrate loading of the chip with far more than 10^7 atoms in roughly a second in a setup of the size of a shoebox. We discuss as a possible spin-off a chip based quantum gravimeter for ground based applications, recently demonstrated with our device. The design is employed for a rocket based test of such an interferometer and will demonstrate the feasibility of a satellite based tests of Einsteins principle of equivalence as pursued by the STE-QUEST mission. The QUANTUS cooperation comprises the group of C. Lämmerzahl (Univ. Bremen), A. Peters (Humboldt Univ. Berlin), T. Hänsch/l.Reichel (MPQ/ENS), K. Sengstock (Univ. Hamburg), R. Walser (TU Darmstadt), and W.P. Schleich (Univ. Ulm).

This project is supported by the German Space Agency Deutsches Zentrum für Luft- und Raumfahrt (DLR) with funds provided by the Federal Ministry of Economics and Technology (BMWI) under grant number DLR 50 WM 0346 and STE-QUEST AI 50 OY 1203. We thank the German Research Foundation for funding the Cluster of Excellence QUEST Centre for Quantum Engineering and Space-Time Research.

[C37.2] The Coolest Spot in the Universe: A Facility for Cold Atom Experiments Aboard the ISS. R.J. Thompson. Jet Propulsion Laboratory, California Institute of Technology, Pasadena CA 91011. Microgravity offers a wealth of advantages for studies of ultra-cold atomic gases and their applications. These include the ability to achieve exceptionally low temperatures via expansion into very weak traps, which don't need to be supported against gravity; the ability to achieve very long interaction times with samples that have been released from traps, and ability of quantum matter-waves to propagate for large distances without perturbation. The Cold Atom Laboratory (CAL) will be a flexible, multi-user ultra-cold atom facility that will enable the precise study of quantum gases at effective temperatures well below the coldest achievable on Earth. CAL will launch to the Space Station by the end of 2015, allowing scientists to access a novel regime with temperatures just a few trillionths of a degree above absolute zero, a regime in which quantum phenomena can be observed on a macroscopic scale.

CAL is supported by SLPS and ISS-PO.

[C37.3] Hybrid Magnetic and Optical Atom Chip Technology for Cold and Ultracold Matter Systems. Seth C. Caliga, Cameron Straatsma, and Dana Z. Anderson. Department of Physics and JILA, University of Colorado, Boulder CO, USA. Compound silicon and glass atom chip technology provides a pathway towards miniaturizing and integrating cold and ultra cold atom timekeeping, sensor, and measurement systems. Glass portions of the chip allow optical access to atoms while both the silicon and glass can be metalized to enable atoms to be manipulated using magnetic fields. When the chip is used to seal a vacuum cell, on-chip Ultra-High-Vacuum (UHV) compatible electrical feed-throughs provide a compact means of making electrical connections from ambient to vacuum. We use compound substrate technology to implement a hybrid magnetic and optical trap to demonstrate a matter-wave oscillator. A magnetic trap is used to produce a Bose Einstein Condensate (BEC) while light beams projected through a transparent (window) portion of the chip are used to form a transistor-like atomic potential. The window also allows in-trap imaging with an optical numerical aperture of 0.6. We are currently developing on-chip optics to implement optical lattices and similar structures that will extend still further the capability of atom chips and miniature ultra cold matter systems.


The Center of Applied Space Technology and Microgravity (ZARM) founded by Prof. Dr.-Ing. Hans J. Rath in 1985 is part of the Department of Production Engineering at the University of Bremen, Germany. ZARM established as a research center and currently headed by Prof. Dr. Claus Lämmerzahl is mainly concentrated on fundamental investigations of gravitational and space-related phenomena under conditions of weightlessness as well as questions and developments related to technologies for space. At ZARM more than 70 scientists, engineers and administrative staff as well as many students from different departments are employed. Today, ZARM is still one of the largest and most important university institutes for space sciences and technologies in Europe as well as worldwide accepted in the space community. With a height of 146 m the Drop Tower Bremen is the predominant facility of ZARM and also the only drop tower of its class in Europe. ZARM’s ground-based laboratory offers the opportunity for daily short-term experiments under conditions of high-quality weightlessness at a level of 10^-5 g (microgravity). The provided quality is one of the purest for experiments under weightlessness worldwide achieved. The scientists may choose between a single drop experiment with 4.74 s in simple free fall and a catapult experiment with 9.3 s of weightlessness. Either in the drop or in the worldwide unique catapult operation routine the repetition rates of microgravity experiments at ZARM are always the same, generally up to 3 times per day. Since the start of operation of the facility in 1990, over 6500 launches of more than 150 different experiment types from various scientific fields like Fundamental Physics, Combustion, Fluid Dynamics, Planetary Formation / Astrophysics, Biology and Materials Sciences have been successfully accomplished so far. In this paper future prospects in research under space conditions at the Drop Tower Bremen will be presented including an update on our planned novel facility, the GraviTower Bremen, and an outlook of upcoming experiments and projects.

The Cold Atom Laboratory (CAL) will be a multi-user facility for the study of ultra-cold quantum gases in the microgravity environment of the International Space Station (ISS). CAL is being developed by the Jet Propulsion laboratory (JPL) for the Human Exploration Mission Directorate (HEOMD) and is scheduled to launch in early 2016 on a Pressurized Cargo Vehicle. After docking with ISS, the CAL payload will be installed by astronauts into an EXPRESS (EXPedite the PRocessing of Experiments to Space Station) Rack inside the space station.

The CAL instrument uses the principle of laser, adiabatic, and evaporative cooling to create a Bose Einstein Condensate. In the microgravity environment of the ISS temperatures on the order of 10 picokelvin can be achieved with interaction times on the order of ten second, and order of magnitude improvement over Earth-Based laboratories. CAL will provide new scientific insight into the properties matter waves, only visible in this ultra-cold regime.

The heart of instrument configuration consists of a vacuum assembly inside of which is a Rubidium and Potassium Source. The atoms are released, directed and constrained by electric and magnetic fields. The atoms experience two stages of laser cooling followed by evaporative cooling on cooling whilst constrained on an atom chip. The “shirt-sleeve” environment of space station allows the use of commercial electronics, lasers, and optics, to create, image, and record the properties of the ultra-cooled gas enabling a low-cost and rapid development timeline for delivery to ISS. The instrument is operated remotely from JPL, and data received real-time with a link to the TDRS satellite.

This paper will present the instrument technology choices, development status, implementation approach, and concept of operations. Supported by NASA’s Space Life and Physical Sciences and the NASA ISS Program Office.

**CONCURRENT SESSIONS 34-38**
**THURSDAY, NOVEMBER 7, 2013 (10:30 AM – 12:00 PM)**

[C38.1] Soot Formation in a Coflow Jet Flame under Microgravity and Normal Gravity. B. Ma1, S. Cao1, D. Giassi1, D. P. Stocker2, F. Takahashi1, B.A.V. Bennett1, M.D. Smooke1, M.B. Long1. Yale University, New Haven, CT, USA; 1NASA Glenn Research Center, Cleveland, OH, USA; 2National Center for Space Exploration Research, NASA Glenn Research Center, Cleveland, OH, USA.

From the Structure and Liftoff in Combustion Experiment (SLICE), conducted on the International Space Station in early 2012, a comprehensive and unique set of microgravity coflow diffusion flame data was obtained that covers weak flames near extinction to strong, highly sooting flames. This enabled a study of the gravitational effects on phenomena such as soot formation in CH4 and C2H4 coflow jet flames. Comparison normal-gravity tests were subsequently conducted and computational simulations were carried out to facilitate understanding of the experimental observations. Experimentally, the flame shape and size, lift-off height, and soot temperature were determined from line-of-sight flame emission images taken with a color digital camera. Soot volume fraction was determined by performing an absolute light calibration using a thermocouple. The microgravity sooting flames are found to have lower soot temperatures and higher volume fraction compared to their normal-gravity counterparts. The soot distribution tends to shift from the centerline of the flame to the wings from normal gravity to microgravity. Computationally, the vorticity-velocity formulation of the governing equations was employed to describe the chemically reacting flow, and the resulting system of fully coupled, highly nonlinear equations was solved by a damped, modified Newton’s method. The two-dimensional axisymmetric model coupled finite-rate chemistry in the gas phase with the aerosol equations in the sectional representation. The formulation included detailed treatment of the inception, surface growth, oxidation, coalescence and thermophoresis of soot particulates. The influence of soot formation on radiative heat loss and scavenging of gaseous species was also taken into consideration. The unique set of data serves as an excellent test case for developing more accurate computational models.


The electrical properties of flames have been known for 500 years, but only in the mid-20th century did the combustion science foundation of these properties begin developing. Periodic interest in the weak plasma character of flames has led to valuable but relatively modest additional insights regarding the potential application of electric fields to control combustion processes. One of the challenges to a more complete understanding of these processes is the confounding effects of buoyancy. For example, recent research has been directed towards electric-field based active combustion control mechanisms and diagnostic tools, and in particular the correlation between ion-driven winds and flame behavior. The ion-driven wind occurs when an external electric field is applied to a flame, and the naturally occurring ions transfer the momentum they acquire from the field to the bulk gas. The ion-driven wind alters the flow environment and has been shown to have a strong effect on flame structure, luminosity, and stability limits. Because the ion-driven wind behaves very similarly to a buoyancy-driven wind, however, clearly separating these components in 1-g is difficult. Hence, studying the flame behavior within an electric field in a microgravity environment serves two purposes; improving the fundamental understandings of these behaviors without the interference of convective forces created by buoyancy and advancing the knowledge of potential applications of flames in space. This paper will describe initial ground-based experiments that were performed in preparation of the microgravity experiments. In addition, experiments under microgravity conditions will be described which include drop-tower tests, ISS experiments planned, as well as experiments showing how an electrical field can be used to cancel buoyancy in a 1g environment. Recent advances in numerical simulations which include the electrical body force will...
also be discussed to describe the mechanisms involved in both 1g and μg.
This work is supported by NASA’s ISS Research Project via agreement NNX07AB55A, with Dennis Stocker as contract monitor.

[C38.3] Combustion Limits on Lean Premixed Low-Lewis-Number Counterflow Flames for CH4/O2/CO2 and CH4/O2/Xe mixtures. Tomoya Kobayashi1, Hisashi Nakamura1, Takuya Tezuka1, Susumu Hasegawa1, Koichi Takase1, Masato Katsuta1, Masao Kikuchi2, Kaoru Maruta1. 1Institute of Fluid Science, Tohoku University; 2Tsukuba Space Center, Japan Aerospace Exploration Agency.

The counterflow flame method is one of the most common ways to investigate the extinction limits of deflagration (propagating flame) and the limits obtained by this method were thought to be the fundamental limit for a flame. Meanwhile, theoretical, numerical, and experimental investigations revealed that spherical flames that do not propagate, flame balls, could exist in the vicinity of the counterflow flame limit under microgravity environments. Flame balls were firstly predicted by Zeldovich and space experiments in STS-83 and STS-94 confirmed that flame balls could be stable for more than 500 s. However, since the counterflow flames and flame balls were investigated separately, there are no attempts to bridge these two flames. Therefore, the final goal of this research is to provide a comprehensive understanding on extinction limits and to provide a benchmark database connecting the counterflow flames and flame balls. The extinction limits of premixed counterflow flames for CH4/O2/Xe and CH4/O2/CO2 mixtures with Lewis numbers lower than unity were obtained both experimentally and numerically. A non-adiabatic 1-D numerical simulation code based on PREMIX was used resulting in a G shaped extinction curve on an equivalence ratio - stretch rate plane. Experiments were conducted on an airplane in parabolic flight for lower stretch rates and on the ground for higher stretch rates. Experimental results show that counterflow flames cannot maintain their planar shapes at extremely low stretch rates. At stretch rates lower than 13.8 s\(^{-1}\) for CH4/O2/Xe flames and 4.9 s\(^{-1}\) for CH4/O2/CO2 flames, ball-like flames were formed before extinction. To obtain a complete transition behavior between counterflow flames and flame balls, experiments on the KIBO module of the ISS is scheduled on 2016. Comparisons between the present experimental results and numerical simulations will be discussed. This result will bridge the gap between deflagration and flame balls leading to a universal understanding on extinction limits. The present revelation is also fundamentally important for a modeling of turbulent flames and the development of combustion devises with high efficiency.

Supported by the Japan Aerospace Exploration Agency and the Japan Space Forum.

[C38.4] Burner-Stabilized Gaseous Flames for the Combustion Integrated Rack. D.P. Stocker1, F. Takahashi2, J.M. Hickman1. 1NASA Glenn Research Center, Cleveland, OH, USA; 2National Center for Space Exploration Research, NASA Glenn Research Center, Cleveland, OH, USA.

In 2016, it is expected that the Combustion Integrated Rack (CIR) research on the space station will transition from droplet combustion to burner-stabilized gaseous flames, where the latter is under the Advanced Combustion via Microgravity Experiments (ACME) project. The five currently planned ACME experiments are focused on improving both practical terrestrial combustion and spacecraft fire safety. More explicitly, their goals are to improve our understanding of materials flammability (through emulation where the gaseous burner is equipped with heat flux sensors), combustion at fuel lean conditions where both optimum performance and low emissions can be achieved, flame stability and extinction limits, soot control and reduction, oxygen-enriched combustion which could enable practical carbon sequestration, and the use of electric fields for combustion control. This research breadth is possible because of the modular nature of the ACME hardware and software which is now in development. Exchangeable (or simply removable) elements include the burner, a thermocouple rake, a radiometer array, a set of three photomultiplier tubes, a fiber array for thin-filament pyrometry, the electric field components, and the suite of optical diagnostics (e.g., cameras) located outside of the CIR’s combustion chamber. While the five planned ACME experiments are studies of laminar non-premixed (i.e., diffusion) flames, the hardware is also capable of supporting studies of turbulent and/or premixed flames. Through its modular design, ACME will enable future experiments with a wide variety of burner-stabilized gaseous flames.
The Veggie plant/vegetable production system is scheduled to fly
on ISS at the end of 2013. Since much of the technology associated
with Veggie has not been previously tested in microgravity,
a hardware validation flight was initiated. This test will allow data to
be collected about Veggie hardware functionality on ISS, allow crew
interactions to be vetted for future improvements, validate the
ability of the hardware to grow and sustain plants, and collect data
that will be helpful to future Veggie investigators as they develop
their payloads. Additionally, food safety data on the lettuce plants
grown will be collected to help support the development of a
pathway for the crew to safely consume produce grown on orbit.
Significant background research has been performed on the Veggie
plant growth system, with early tests focusing on the development of
the rooting pillow concept, and the selection of fertilizer, rooting
medium and plant species. More recent testing has been conducted
to integrate the pillow concept into the Veggie hardware and to
ensure that adequate water is provided throughout the growth
cycle. Seed sanitation protocols have been established for flight,
and hardware sanitation between experiments has been studied.
Methods for shipping and storage of rooting pillows and the
development of crew procedures and crew training videos for plant
activities on-orbit have been established. Science verification
testing was conducted and lettuce plants were successfully grown in
prototype Veggie hardware, microbial samples were taken, plant
were harvested, frozen, stored and later analyzed for microbial
growth, nutrients, and ATP levels. An additional verification test,
prior to the final payload verification testing, is desired to
demonstrate similar growth in the flight hardware and also to test a
second set of pillows containing zinnia seeds. Issues with root mat
water supply are being resolved, with final testing and flight
scheduled for later in 2013. Hardware validation supported by
NASA.

[C39.3] Instrumentation Development for Experiments in µ- and
hyper-Gravity. Ch. J. Schwarz1, 1Life and Physical Sciences
Instrumentation and Life Support Section, Mechanical Engineering
Department, ESTEC-Esa, NL.

Conducting experiments under micro gravity conditions requires
the adaption of scientific instrumentation to the space environment.
Size, mass, power consumption and interfaces are of major concern
here and need to be adapted accordingly. Moreover new concepts of
instrumentation are developed in order to achieve certain
experimental objectives. In this paper a report is given on recent
and current technology developments of physical science
instrumentation under the framework of ESA’s TRP and GSTP
programs. These developments typically result in a breadboard at
technology readiness level 4. Results of recently completed
projects, such as an improved pqCT x-ray scanner for bone density
measurements and a time correlation spectroscopy setup for the
investigation of spatiotemporal phenomena of colloidal systems will
be presented as well as summaries of on-going projects on
microscopy instrumentation for cell culture systems and a high
speed infra-red camera. Finally an outlook is given on future
projects. Using these breadboards in a parabolic flight or the large
diameter centrifuge (LDC) at ESTEC/ESA will allow to extend the
range of these experiments to the hyper-gravity regime.

[C39.4] Plant Habitat: The Largest Plant Growth Hardware Destined
for Implementation on ISS. H.G. Levine1, E.C. Smith2, A.
Hongamen2, J.D. Gobaira2, M.G. Parris2, K.C. Maloney3, B. Lutinski2,
A.H. Folensbee2, L.B. Roberson2, P.W. Tang2, B.G. Onate1. 1NASA
Utilization and Life Science Directorate, Kennedy Space Center, FL,
USA. 2NASA Engineering Directorate, Kennedy Space Center, FL,
USA.

NASA is developing a large Plant Habitat (PH) to facilitate
fundamental biology and bioregenerative studies on ISS with
relatively large plants under precisely controlled environmental
conditions. The PH will be configured as a quad-locker plus ISIS
drawer payload to be mounted in a standard EXPRESS Rack in the
U.S. Laboratory. It will integrate proven microgravity plant growth
technologies with newly developed fault tolerance and recovery
technologies to increase overall efficiency, reliability, and robustness
and will allow for experiment lengths of 135 days. The design is
based on an open architecture concept that provides the ability to
replace or upgrade critical systems while on orbit. Most
experiments will be initiated using seeds launched dry within a
“Science Carrier” that will be inserted into the base of the PH Growth Chamber. Once the Science Carrier is installed, PH will be activated and proper operation validated. Water will then be delivered to the Science Carrier’s root zone (initially baselined as being composed of 0.5-2.0 mm arcellite with slow release Osmocote fertilizer pellets distributed within) and seed germination initiated. The capability to command environmental control parameter set points will be provided both on-orbit and from the ground. Crew will be able to obtain specimen samples at any point within an experiment (e.g. for pollination, chemical preservation, cold storage, etc.) using sleeved access ports. They will also be able to manually obtain water samples and/or gas samples from internal reservoirs and the shoot and root zones. Plant growth, water usage and other physiological parameters will be monitored using non-invasive measurements of chamber CO2, O2, canopy temperature and root zone moisture content. Direct observation of the plants will be possible at any time via a transparent front panel (nominally blocked by a light-tight cover), and indirect viewing will be possible (both on-orbit and on the ground) via both side and top-mounted cameras (enabling assessments of plant growth, leaf area development, etc.). An overview of PH’s design at the 30% level will be presented.

Supported by NASA’s International Space Station Program Office, NASA’s Life and Physical Sciences Division, and Kennedy Space Center’s Utilization and Life Sciences Directorate.

[C39.5] Miniaturized system for partial-gravity and microgravity experiments on the ground. Katsuya Hasegawa1, Masamitsu Kawamoto1, Tomomi Kawasaki1, Ayumi Kurihara2, Shuji Aou2, and Yasuhiro Kumei. 1Japan Aerospace Exploration Agency, 2Graduate School, Kyushu Institute of Technology, 3Graduate School, Tokyo Medical and Dental University.

In the past half century, the parabolic flight has been operated for the purposes of scientific researches and astronaut training in microgravity conditions to simulate space flight environment. Besides microgravity, we have been cultivating life science researches on partial-gravity conditions by using our original trajectory of parabolic flight. In order to enable further space exploration into the moon, Mars, and other planets, it is essential to understand the physiological response to partial-gravity environments. However, studies using partial-gravity conditions have not been conducted sufficiently due to the extraordinary high cost for conducting experiments aboard spaceflights or even parabolic flights. The purpose of the present study is to develop the radio-controlled miniaturized multicopter system that is used for the controlled falling vehicle (not free fall). During the controlled falling, the payload is exposed to a certain level of partial gravity. Functions of the multicopter are shown as follows. 1) G profile: wide-range of partial-gravity conditions from 0 to 1 G that will last approximately 5-20 seconds, 300m elevation above the ground. 2) It changes to the low gravity without passing through the high-gravity. 3) Payload 20 kg, 4) 10 minutes to re-take off from landing, it is possible to experiment repeatedly with short cycle. 5) Supply limited imaging techniques, high-speed video and photography, images can be monitored on the ground. 6) All data is recorded in the memory on multicopter. Some data monitored on the ground. 7) Operated from the ground 16 functions in flight. The current prototype is designed for experimentation on various model organisms, from cells to animals and plants. The novel multicopter flight system enables daily conducting experiments in partial-gravity conditions with less than 1% of the budget for spaceflight or parabolic flights. We can expect reproducible results from many repeated trials at the lowest cost.

[C39.6] Growth of Terrestrial Microorganisms under Martian Conditions. Andrew C. Schuerger1 and Wayne L. Nicholson2. 1Dept. of Plant Pathology and 2Dept. of Cell and Microbiology, University of Florida, 505 Odyssey Way, Space Life Sciences Lab at Exploration Park, North Merritt Island, FL 32899; emails: schuerg@ufl.edu; wln@ufl.edu.

The search for life on Mars is assisted by characterizing the limits of growth by terrestrial microorganisms under Martian conditions. We have successfully grown several bacteria, but no fungi or archaea, under Martian conditions of 7 mbar, 0°C, and CO2-enriched atmospheres. First, the generalist, Serratia liquefaciens, was observed to form visually discernible microcolonies on trypticase soy agar (TSA) in 14-21 days (Schuerger et al., 2013, Astrobiology, 13, 115-131). Second, several Carnobacterium spp. exhibited faster growth at the above conditions forming observable colonies on TSA within 7-10 days (Nicholson et al., 2012, PNAS, 110(2), 666-671). And third, ongoing experiments have recovered additional hypobarophiles from diverse ecological niches including Siberian permafrost, Arctic soils, alpine soils, seawater, and human saliva. All other bacteria tested (i.e., 50+ mesophilic species from spacecraft and hundreds of species from Siberian permafrost, Arctic soils, etc.) failed to grow under Martian conditions. Ongoing 16S sequencing of recovered bacterial hypobarophiles indicates that tolerance to 7 mbar is widespread in bacteria with members from the following genera so far identified: Cryobacterium, Exiguobacterium, Leuconostoc, Paenibacillus, and Streptomyces. In soil assays for hypobarophiles at 7 mbar, between 10^5 to 10^6 total bacteria and 10^2 to 10^3 total fungi were recovered per gram of soil. In contrast, the numbers of the recovered bacterial hypobarophiles were in the range of 10^1 to 10^2 per gram of soil tested. Ongoing research focuses on characterizing the effects of Martian pressure (7 mbar) on the metabolic, genomic, and ultrastructure changes in Serratia liquefaciens and Carnobacterium spp.

Supported by grants NNX08BAQ1A and NNX12AJ84G from the Planetary Protection Office, NASA, Washington, DC.

Concurrent Session 40: Vertebrates 4
Session Chair: Joe Tash, University of Kansas Medical Center
Time: Thursday, 2:00 pm – 3:30 pm

[C40.1] Overcoming Cardiovascular Challenges of Interplanetary Flight: May the Force of Pressure be with You. Alan R. Hargens. Department of Orthopaedic Surgery, University of California, San Diego, San Diego, CA 92103-8894, USA, Email: ahargens@ucsd.edu.

A simple, low cost, low mass, low power device is needed to provide artificial gravity during a prolonged mission such as to Mars. Our previous research involving use of exercise within lower body negative pressure (LBNP) addresses several risk factors and critical questions in Critical Path Road Maps related to countermeasures against fluid shifts, elevated intracranial pressure, and musculoskeletal and cardiovascular losses associated microgravity. Fifteen sets of identical twins (16 males and 14 females, 21-48 years)
remained in 6 degree head-down-tilt, bed rest for 30 days to simulate microgravity. One twin from each pair (EX) was randomly selected to exercise supine in our LBNP chamber for 40 min at 1.0-1.2 body weights for six days per week. Their twin siblings served as non-exercise controls (CON). Orthostatic tolerance (time to presyncope) and sprint speed decreased significantly (p<0.05) after 30 days bed rest in the CON group, but was relatively maintained in the EX group. Upright peak oxygen consumption (VO2pk), muscle strength, and endurance decreased significantly in CON group, but these functional parameters were preserved in the EX group. Also, the EX group had significantly higher back muscle strength and lower lumbar-spine compressibility after bed rest than the CON group. We also performed 60 day bed rest studies in France as a part of WISE-2005. Results from these 60 day studies were similar to the 30-day twin studies at UCSD. The efficacy of our integrated exercise countermeasure is documented during simulated microgravity and translated to orthopaedic benefit with respect to rehabilitation of athletes and orthopaedic patients.

Supported by NASA, ESA, CSA, and CNES; by NIH grant M01 RR00827; and by NASA Grants NAG9-1425 and NNU04HF71G. We thank the identical twin and European women volunteers and UCSD GCRC and MEDES staff.

[C40.2] Modeling of the Cephalad Cerebrospinal Fluid Shift Contribution to Elevated Intracranial Pressure in Microgravity. R.W. Tain1 and N. Alperin1, 2. 1Department of Radiology, Miller School of Medicine, and 2Biomedical Engineering, University of Miami, Miami, FL, USA.

Visual and ocular changes including optic disc edema, optic nerve sheath distension, posterior globe flattening, and hyperopic shift have been reported during and after long-term spaceflights. This is known as the visual impairment and intracranial pressure (VIIP) syndrome. The exact mechanism of VIIP is not clear. Current understanding suggests that VIIP is caused by cephalad fluid shifts that result with elevated intracranial pressure (ICP). Investigations to date focused on the influence of plasma and blood cephalad shifts on the ICP in microgravity. The impact of the cerebrospinal fluid (CSF) cephalad shift, i.e., spinal-to-cranial CSF volume redistribution, on ICP in microgravity has not been previously considered. This work simulates the contributions of cephalad plasma and blood shifts and the spinal-to-cranial CSF shift to elevated ICP using a lumped parameter modeling. The proposed model is an extension of our previously reported craniospinal compartmental model used to explore the role of the spinal canal compartment in idiopathic intracranial hypertension (IIH). The effect of microgravity was simulated using postural related changes in the hydrostatic forces. The model was applied to predict the change in ICP following a postural change from supine (0°) to an upward body tilt posture (20°). This postural maneuver was chosen because it can be reproduced inside an MRI scanner for validation. The model successfully demonstrated the expected increase in ICP due to the spinal-to-cranial CSF volume shift, and the increase in intracranial interstitial fluid volume. In the absence of the influence of the cerebrospinal fluid, the increase in interstitial fluid volume still appears to increase intracranial pressure. However, this requires an unlikely caudal shift of CSF from the cranium to the spinal canal. It is unlikely that a caudal CSF shift occurs in microgravity as increase, and not decrease, in intracranial CSF volume was shown to facilitate optic disk edema in IIH. This study implies that cephalad spinal-to-cranial CSF shift occurs in microgravity and plays a primary role in the development of microgravity induced intracranial hypertension and visual impairments.

Supported in part by National Institute of Health award 5R01NS052122.

[C40.3] Investigating the Relationship Between Ocular Blood Flow and Intracranial Pressure Towards a Noninvasive Measurement Methodology. J.A. Hawks1, M. Twedt2, T. Ketchem2, D. Lim3, G. Bashford4, 1Dept. of Mechanical & Materials Engineering, 2Dept. of Biological Systems Engineering, University of Nebraska, Lincoln, NE, USA; 3Dept. of Biomedical Engineering, Duke University, Durham, NC, USA.

Long duration space missions have shown the remarkable extent of adaptation of the human body to microgravity environments. Many of these adaptations are not fully understood, including vision impairments experienced by astronauts during spaceflight. In addition to decreases in visual acuity, long term changes to the ocular structure have been observed. These include optic nerve sheath distention and globe flattening. It is suspected that elevated intracranial pressure (ICP) induced by microgravity and spaceflight conditions is a significant factor in these changes. Discrepancies between astronaut symptoms and terrestrial cases of elevated ICP suggest a more complicated issue, however. A lack of in-flight ICP monitoring techniques has made it difficult to observe ICP levels throughout space missions can offer valuable insight towards understanding the effects and physiological adaptations of the body in microgravity, which is crucial as we look to send astronauts on longer missions. A proposed technique to correlate changes in characteristics of ophthalmic blood flow velocity in response to an applied force under different ICP levels has shown promise. By applying small forces to the front of the eye with a controlled actuator, we can observe changes in the blood flow velocity through the ophthalmic artery using Doppler ultrasonography. Increased force increased the flow velocity until a critical inflection point before velocity decreases up to occlusion of the artery. Changes in ICP affect the material properties surrounding the artery and the force required to reach this inflection point. Charting changes in this force value allows the degree of ICP change to be determined. Testing of this method utilizing silicone models of the ocular structure has shown that less than 2.5 lbs of force applied to the eye is sufficient to generate noticeable changes in flow velocity through an internal vessel. Preliminary results have also shown that the strain rate of the applied force also relates to the amount of force needed to alter blood flow velocity. Data collection on human subjects, and the testing of swine subjects with elevated ICP is needed to validate the accuracy and reliability of this methodology for noninvasive ICP monitoring.

Supported by NASA Nebraska Space Grant Consortium.

[C40.4] Human brain in microgravity: accuracy, precision, sensitivity and specificity of non-invasive intracranial pressure measurements. A. Ragauskas1, R. Zakelis1, V. Petkus1, G. Daubaris1, L. Bartusis1, R. Chomsakis1. 1Kaunas University of Technology, Telematics Science Laboratory, Kaunas, Lithuania.

Background: An innovative absolute intracranial pressure (aICP) measurement method has been validated by multicenter
Comparative clinical studies. Method is based on two depth TCD technology and employs intracranial and extracranial segments of the ophthalmic artery (OA) as a pressure sensors. The OA as a natural pair of scales which compares aICP with controlled pressure Pe which is externally applied to the orbit. In the case of scales’ balance aICP=Pe. Two depth TCD device is used as a pressure balance indicator. The proposed method is the only non-invasive aICP measurement method which does not need a patient specific calibration. Objectives: To validate the accuracy, precision, linearity, sensitivity and specificity of proposed non-invasive aICP measurement method by multicenter comparative clinical studies on wide groups of neurological and ICU patients. Methods: Prospective randomized comparative clinical studies (including blinded studies) of simultaneous non-invasive aICP and “gold standard” invasive ICP measurements. Data collected from 110 patients (171 independent paired data points). Bland and Altman and ROC analyses have been performed. Results: Accuracy of non-invasive aICP meter (expressed by the mean systematic error Δ) is Δ = 0.03 mmHg, CL = 0.97. Precision of aICP meter (expressed by SD of random error) is SD = 2.65 mmHg (CL = 0.97). ROC analysis showed an area under ROC curve AUC = 0.94 with sensitivity 73.7 % (CL = 0.95) and specificity 94.7 % (CL = 0.95). Conclusions: Close to ideal linearity of non-invasive aICP measurement technology, negligible systematic error and low enough random errors’ SD of random errors were observed in a wide range of aICP values from 5 mmHg to 30 mmHg. Clinically validated method shows practically acceptable accuracy, precision, sensitivity and specificity. The statistically significant clinical validation results support hypothesis on no need of calibration to the individual patient or healthy person of created aICP measurement method.

Clinical studies and technology development were funded by European Commission Framework 7 projects “TBIcare”, “BrainSafe”, “BrainSafeII”, by the US Dept. of the Army and partially by NASA.

Concurrent Session 41: Fundamental Physics 5 – Atom Interferometry

Session Chair: Garry Burdick, NASA Jet Propulsion Laboratory

Time: Thursday, 2:00 pm – 3:30 pm

[C41.1] Precision measurement and tests of the equivalence principle by atom interferometry in space. Holger Müller, Physics Department, UC Berkeley, Berkeley, CA 94720, USA.

Gravity is equivalent to acceleration, and accelerates all objects in the same way, no matter what they are made of. This concept, known as the Einstein Equivalence Principle (EEP), is the foundation of general relativity. Experimental tests of Lorentz invariance, local position invariance, and the weak equivalence principle (WEP) have shown that nature adheres closely to this principle. These tests are motivated by the quest to unify the theories of gravity and quantum mechanics: the natural energy scale for this unification is the Planck scale, where corrections to general relativity are expected to appear, but where direct experimentation is impossible. Nevertheless, we can search for suppressed effects at attainable energy scales via experiments of outstanding precision. Violations of WEP are among the most promising candidates for such low-energy signals of Planck-scale physics. Quantum tests of the weak equivalence principle will test the WEP to an improved precision by comparing the evolution of matter waves of different species of ultracold atoms. We will compare quantum tests to classical tests; ground-based tests to space tests, and make a case for an improved test of the EEP on the space station or a freely flying satellite. We will discuss technical developments that can strongly enhance the accuracy of such a mission relative to its competitors.

[C41.2] Prospects for Gravitational Wave Detection with Atom Interferometry. Jason M. Hogan, Susannah M. Dickerson, Peter W. Graham, Surjeet Rajendran, Alex Sugarbaker, and Mark A. Kasevich. Department of Physics, Stanford University, Stanford, California 94305 USA.

Atom interferometry has the potential to be a powerful tool in the ongoing search for gravitational waves. I will discuss our proposals for detection of gravitational waves using high precision atom interferometry. Gravitational waves can be observed by comparing a pair of atom interferometers separated by a km-scale baseline, potentially offering compelling strain sensitivities in the 1 mHz to 10 Hz frequency range. These proposals rely on the core technology being developed at the Stanford 10-meter atomic fountain. I will report on our recent realization of a light-pulse atom interferometer with 1.4 cm peak wavepacket separation and a duration of 2T = 2.3 seconds.

Supported in part by NASA GSFC Grant No. NNX11AM31A.

[C41.3] Atom Interferometry and its Applications in Space. Jason Williams, James Kellogg, Thierry Botter, James Kohel, and Nan Yu. Jet Propulsion Laboratory, California Institute of Technology, CA, USA.

Atom interferometers utilize the wave-nature of atomic and quantum gases for precision measurements of inertial forces, with applications ranging from high-sensitivity accelerometers and gyrosopes to novel devices for testing the paradigms of fundamental physics. The high stability and sensitivity intrinsic to these devices already place them among the best sensors available for measurements of accelerations, rotations, and gravity gradients, with the promise of several orders of magnitude improvement in the fundamental detection limits of these devices. However, matter-wave interferometers using free atomic gases must often compromise between high sensitivity, scaling as the square of their interrogation times, and system size, given by the free-fall times of the gases. The realization of matter-wave interferometers in the microgravity environment of space resolves this compromise, promising orders of magnitude improvement in measurement sensitivity. We will describe JPL’s efforts in the development of atom interferometer technology and investigations of its applications in space. We will also discuss our interests in the use of space-based atom interferometry for tests of fundamental physics laws, earth and planetary sciences, and eventual application in detection of gravitational waves. We will report on our recent progresses in the JPL atom interferometer instrument and study of using atom interferometers for quantum test of Equivalence Principle as part of collaborations with the ESA QWEP project.

This research was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration.
The conventional ΛCDM cosmological model supplemented by the inflation concept explains the Universe evolution well. However, there are still a few concerns: New Planck data impose a non-trivial constraint on the shape of the inflation potential, which excludes many inflationary models; the dark matter is not detected directly; and the dark energy is not described theoretically on a satisfactory level. Within the FLRW formalism we consider a model of the closed Universe (with the spherical spatial topology), filled with the additional perfect fluid with the constant parameter -1/3 in the line equation of state (which may be called quintessence). We compare this model with the standard ΛCDM and answer the following question: can this additional fluid lead to light traveling between the antipodal points during the current age of the Universe? This possibility could strongly affect the inflation scenario which may completely lose its necessity.

Supported by NASA (NNX09AV07A) and NSF (HRD-0833184).

**Concurrent Session 42: Combustion 3 – Microgravity Fire Safety and Flammability (Part I)**

**Session Chair:** Paul Ferkul, NASA Glenn Research Center

**Time:** Thursday, 2:00 pm – 3:30 pm

**[C42.1] Burning and Suppression of Solids – II Fire Safety Investigation for the Microgravity Science Glovebox.** Sandra L. Olson1, Paul V. Ferkul2, Subrata Bhattacharjee3, Fletcher J. Miller3, A. Carlos Fernandez-Pello4, and James S. T’ien5. 1NASA Glenn Research Center; 2National Center for Space Exploration Research; 3San Diego State University; 4University of California at Berkeley; 5Case Western Reserve University.

Burning and Suppression of Solids – II (BASS-II) will utilize the same small flow duct hardware used in the precursor BASS experiment within the Microgravity Science Glovebox (MSG) for observations of burning solid materials on board the ISS. Recent BASS experiments demonstrated the capability to vitiate the MSG working volume, so additional tests have been planned to take advantage of that added capability. The main variables to be tested in BASS-II are the effects of ambient oxygen concentration, ventilation flow velocity, and fuel type, thickness, and geometry.

BASS-II consists of 100 fuel samples and associated igniter wires. There are three categories of samples: flat samples, rod samples, and a section of a large solid sphere. Thin flat samples (8.5 cm long by 1 and 2 cm wide) yield concurrent or opposed-flow spread rates, limiting flame lengths, and extinction limits. The flat sample materials will include acrylic films and sheets of different thicknesses, and a cotton-fiber glass fabric blend which was previously tested in BASS. The rod samples are made of black or clear acrylic, and will provide solid fuel regression rates and extinction limits for both opposed and concurrent flow. The large solid spherical section, also made of acrylic, will be used to study ignition of thick materials and flame growth over the thick material. Many of the tests will focus on finding a minimum oxygen concentration or flow velocity where a material will burn in space, to compare with the Earth-based flammability limits. The crewmember is directly involved with the investigator team throughout the experiment to load fuel samples, seal the working volume, adjust gaseous nitrogen vitiation, ignite the fuel, monitor the test, adjust flow rates, take still photographs, and provide additional observations about the test.

This work was supported by the NASA Space Life and Physical Sciences Division (SLPS).

**[C42.2] Overview of the Solid Combustion Experiment in the Japanese Experimental Module “Kibo” on the ISS.** M. Kikuchi1, T. Mizushima1, O. Fujita2, Y. Nakamura3, S. Takahashi3, A. Ito4, H. Torikai5, and S.L. Olson7. 1JAXA, Japan; 2Hokkaido University, Japan; 3Gifu University, Japan; 4Hirosaki University, Japan; 5NASA GRC, USA.

Fire safety in manned spacecraft or space station is one of the most important requirements for any manned space mission. To prevent fires in space, material flammability tests such as NASA-STD-(1)-6001B standards have been widely employed. The tests are performed in normal gravity environment. Previous research showed material flammability could be higher in microgravity environment for some conditions, so it is important to understand the impact of gravity-induced buoyant flow on material flammability. In 2010, the investigation titled “Quantitative Description of Gravity Impact on Solid Material Flammability as a base of Fire Safety in Space (Solid Combustion)” was selected by the Japan Aerospace Exploration Agency (JAXA) as an experiment candidate in the Japanese Experiment Module “Kibo” on the International Space Station (ISS). In the “Solid Combustion”, three types of solid material (polyethylene insulated wires, thin PMMA sheets and thin fiber papers) are selected as test samples. Flammability of these materials will be quantitatively determined in microgravity by evaluating 2 fundamental events of solid combustion, which are (1) ignition of the solid material, and (2) flame spread over the solid material. It is expected that the discussion of the discrepancy between the data in normal gravity and microgravity will lead to improved understanding of the conservatism of the existing material flammability tests. Also, a “material flammability map” for the selected samples will be produced as a fire safety database for spacecraft, which could be reference data to estimate flammability of other solid materials. At present, a detailed consideration of the experimental plan in orbit as well as a conceptual design of the experiment specific hardware to be installed into the Multi-purpose Small Payload Rack (MSPR) in the Kibo, have been on-going. In this paper, an overview of the “Solid Combustion” experiment and the current status of the project will be presented.

**[C42.3] Burning Characteristics of Paraffin and Japan Wax Candle Flames in a Low-Speed Oxidizing Stream in Microgravity.** F. Takahashi1, P.V. Ferkul2, S.L. Olson2, and V.R. Katta3. 1National Center for Space Exploration Research and NASA Glenn Research Center, Cleveland, OH, USA; 2NASA Glenn Research Center, Cleveland, OH, USA; 3Innovative Scientific Solutions, Inc., Dayton, OH, USA.

The Burning and Suppression of Solids (BASS) experiment was conducted in the Microgravity Science Glovebox (MSG) aboard the International Space Station in 2012 and 2013. This study improves understanding of material flammability and fire suppression in microgravity and provides data for rigorous testing of numerical models, including thermal radiation, soot formation, and detailed
A "candle" consisting of wax cast into an alumina tube (6.35 mm o.d., 4.7 mm i.d., and 26 mm length) together with a fiberglass wick is placed in an oxidizer flow duct (76 mm square cross-section) in the concurrent or opposed flow direction. The fuel is n-paraffin wax (typically C19-C35 hydrocarbon, 55.0-55.6 C m.p.) or Japan wax (triglycerides, 50-53.5 C m.p.), and the oxidizer is air or nitrogen-vitiated air (oxygen mole fraction: ~0.21 or ~0.17, respectively; mean velocity: 0 to ~5 cm/s). The fuel was ignited at a moderate oxidizer velocity to establish a stable flame and was decreased gradually until flame extinction occurred. Although flame suppression was attempted by injecting nitrogen from a tube (500 cc/min, 3.1 mm i.d.) upstream of the candle flame, it induced air flow entrainment into the flame, thereby enhancing the combustion. The transient behavior of the flame was observed using a real-time color video camera and high-resolution still color images were captured using a digital SLR camera and downloaded after the test. A time-dependent, axisymmetric, detailed-chemistry (128 species, 565 elementary reactions) computation with radiation and multi-species transport processes was performed for gaseous n-heptane flames in a candle configuration to reveal the diffusion flame structure.

This work was supported by the NASA Space Life and Physical Sciences Division (SLPS).

**[C42.4] A Novel Apparatus to Counter the Buoyancy Effect in Flame Spread Experiments. S. Bhattacharjee, C. Paolini, E. Padilla, and K. McGrath. Department of Mechanical Engineering, San Diego State University, San Diego, CA, USA.**

Ground based flame spread studies requiring a microgravity condition are typically done in drop towers, airplanes flying with parabolic trajectories, and sounding rockets. The amount of microgravity time varies from 4.5 seconds in the case of the NASA Glenn drop tower, 15 seconds for parabolic flights, and about 3-4 minutes in sounding rockets depending on payload weight. In this work, we present a simple but novel ground-based experimental alternative where the fuel sample is moved upward at about the same velocity of the buoyancy induced flow to create a pseudo microgravity condition. In a terrestrial flame spread experiments, the flow field and the transport mechanism are dominated by the buoyancy induced flow. By moving the sample along side the upward buoyant flow, the blowing velocity of the fuel vapor and the mild relative velocity experienced by the flame leading edge become the characteristic velocities as in a microgravity environment. This hypothesis is put to test in an eight meter high flame tower at SDSU in which, after a sample is ignited in a downward-spread configuration, the sample holder, placed in an open moveable cart, is traversed upward at any desired velocity. If the upward velocity is just right, the relative downward forced flow experienced by the flame may be nullified by the upward buoyancy induced flow. For flame spread over thin fuels, it is well known that the flame spread rate either remains the same or decreases as the opposing flow velocity is increased in a terrestrial environment. In a microgravity environment, on other hand, the flame spread rate increases with the opposing flow velocity. By varying the upward cart velocity in the range 20 cm/s - 30 cm/s, the spread rate from the Flame Tower indeed show the characteristic trend of the microgravity regime - an increase in spread rate with flow velocity.

Supported by NASA with Dr. David Urban serving as the contract monitor.

**[C42.5] Large-Scale Spacecraft Fire Safety Experiments in ISS Resupply Vehicles. G.A. Ruff and D.L. Urban, A.C. Fernandez-Pello, J.S. T’ien, Jose L. Torero, Guillaume Legros, Christian Eigenbrod, Nickolay Smirnov, Osamu Fujita, Adam J. Cowlard, Sebastien Rouvreau, Olivier Minster, and Balazs Toth. NASA Glenn Research Center, Cleveland, OH, USA; UC Berkeley, Berkeley, CA, USA; Case Western Reserve University, Cleveland, OH, USA; University of Queensland, Brisbane, Australia; Université Pierre et Marie Curie, Paris, France; University of Bremen (ZARM), Bremen, Germany; Moscow Lomonosov State University, Moscow, Russia; Hokkaido University, Sapporo, Japan; University of Edinburgh, Edinburgh, UK; Belisama R&D, Toulouse, France; ESA ESTEC, Noordwijk, Netherlands; Technical University of Denmark, Kgs. Lyngby, Denmark.**

Our understanding of the fire safety risk in manned spacecraft has been limited by the small scale of the testing we have been able to conduct in low-gravity. Fire growth and spread cannot be expected to scale linearly with sample size so we cannot make accurate predictions of the behavior of realistic scale fires in spacecraft based on the limited low-g testing to date. As a result, spacecraft fire safety protocols are necessarily very conservative and costly. Future crewed missions are expected to be longer in duration than previous exploration missions outside of low-earth orbit and accordingly, more complex in terms of operations, logistics, and safety. This will increase the challenge of ensuring a fire-safe environment for the crew throughout the mission. Based on our fundamental uncertainty of the behavior of fires in low-gravity, the need for realistic scale testing at reduced gravity has been demonstrated.

To address this concern, a spacecraft fire safety research project is under way to reduce the uncertainty and risk in the design of spacecraft fire safety systems by testing at nearly full scale in low-gravity. This project is supported by the NASA Advanced Exploration Systems Program Office in the Human Exploration and Operations Mission Directorate. The activity of this project is supported by an international topical team of fire experts from other space agencies to maximize the utility of the data and to ensure the widest possible scrutiny of the concept. The large-scale space flight experiment will be conducted on three missions; each in an Orbital Sciences Corporation Cygnus vehicle after it has débörthed from the ISS. Although the experiment will need to meet rigorous safety requirements to ensure the carrier vehicle does not sustain damage, the absence of a crew allows the fire products to be released into the cabin. The tests will be fully automated with the data downlinked at the conclusion of the test before the Cygnus vehicle reenters the atmosphere. The international topical team is collaborating with the NASA team in the definition of the experiment requirements and performing supporting analysis, experimentation and technology development.

Support includes but is not limited to: JAXA, ESA, RSA, the Centre National d’Etudes Spatiales, and the Spacecraft Fire Safety Demonstration Project of the NASA Advanced Exploration Systems Program.
[C43.1] Electrodeposition of Metals in Microgravity Conditions. Kei Nishikawa1, 2, Tetsuo Nishida2, Elizabeth Chassaing3, Michel Rosso1, Takayuki Homma4, 3, Yoshitsugu Sone5, Takehiko Ishikawa3 and Yasuhiro Fukunaka6, 7, 8. 1) Laboratoire PMC, Ecole Polytechnique-CNRS, 91128, Palaiseau Cedex, France; 2) Dept. Energy Sci, & Tech., Kyoto University; 3) IRDEP, UMR CNRS 7174, 6 quai Watier, 78401 Chatou Cedex, France; 4) Dept. of Applied Chemistry, Waseda University; 5) JST-CREST; 6) ISAS/JAXA, Sagamihara, Japan; 7) JAXA ISS Science Project Office; 8) Nanotechnology Research Center, Waseda University.

Metal electrodeposition may generate irregular deposits with various morphologies. Coupling phenomena between the morphological or microstructural variations and ionic mass transfer rate must be fully understood to tailor the interface to create the unique physical properties. For liquid electrolyte, a precise study of these morphologies may be complicated by convective motion like inside International Space Station. Two electrochemical systems were examined: copper electrodeposition in CuSO4 aqueous solution and Li deposition in ionic liquid containing LiTFSI.

Concentration variations in the electrolyte were measured by laser interferometry. For copper, concentration variations were in good agreement with a transient diffusion theory. For lithium, an induction period was noticed for the concentration profile evolution within 20 second microgravity period during a parabolic flight. Due to this incubation period and to the extremely lower diffusivity in ionic liquid, concentration variation evolution must be studied in the microgravity condition maintained over much longer duration period like inside International Space Station.

This presentation is based on the discussion with the members in ESA-ITT directed by Dr. O. Minster, (PI: M. Rosso, Ph. Mandin, O. Magnussen, W. Schwarzer, R. Alkire, D. Lincot, D. R. Sadoway, T. Homma, H. Matsushima).

The present research is partially supported by JST-CREST and JSPS.

[C43.2] ESA’s Planet Precursors Experiment for the ISS: “ICAPS”. A. Orr. ESA/ESTEC, Keplerlaan 1, PO Box 299, NL- 2200AG Noordwijk, The Netherlands.

The ICAPS experiment of the European Space Agency (ESA) addresses planetary science. Its aim is to understand the formation of planetesimals, or planet precursors, by studying the mutual interactions of micron-size dust particles and their agglomeration in conditions representative of pre-planetary conditions. Its goal is also to study the light scattering behaviour of proto-planetary dust aggregates - as they form. Although the basic concept of the experiment is simple, its scientific potential is far-reaching and its technical development is extremely challenging. The start of project phase C/D is currently being prepared. ICAPS is intended to fly in the Columbus module of the International Space Station (ISS). The ICAPS scientific experiment will consist of: a vacuum chamber surrounded by an injection unit for dust particles, several diagnostic tools, particle manipulation tools and a cleaning system to ensure transparent chamber windows and to avoid experiment contamination between different types of dust particles. The diagnostic tools will include photodiodes, polarimeters, overview cameras, microscopes. The tools for particle manipulation consist of an optical manipulation system and a device to confine the particles within the centre of the chamber. This device is currently foreseen to be based on the thermophoretic principle. The most challenging aspects of the ICAPS experiment are, at the moment, the realization of the “thermophoretic” dust confining device, the cleaning of the experiment chamber and windows and the accommodation of all the diagnostic instruments and light sources around a small-sized chamber. This poster describes the science goals of ICAPS, the payload and current status of the project.

On behalf of: ESA’s Science, Project and Operations team, the ICAPS Science Team; CNRS-LATMOS, UPMC (FR), LPCE/CNRS (FR), Technical University of Braunschweig (DE), Universität Duisburg-Essen (DE), Université Laval (CA), Université Libre de Bruxelles MRC (BE), Institute of Astrophysics of Andalucia CSIC (ES).


In these broad topics, International Teams aim to study foam or emulsions in space and the influence of particles thereon; the physics of loosely compacted granular matter; colloids physics and nucleation in macromolecular solutions. The ‘Soft Matter Dynamics’ instrument will provide for the conditioning of samples: foaming of liquid-gas mixtures, emulsification of liquid-liquid mixtures or agitation of granular matter in dedicated cells and their conditioning. It will also provide for the optical diagnostics capabilities necessary to do their characterisation and monitor the dynamics of their coarsening with time. These include an overview camera and light scattering based diagnostics such as Speckle Variance Spectroscopy, Diffusing Wave Spectroscopy and Time Resolved Correlation Spectroscopy. The instrument design allows in orbit exchange of units containing groups of individual cells or an individual cell and its dedicated support systems. The instrument should be operated in the Fluid Science Laboratory in Columbus as of 2016. The ‘Colloidal Solids’ instrument will provide for sample mixing and thermal control in individual in-orbit exchangeable cells (4 types will be studied) as well as the advanced light scattering capabilities necessary to document the dynamic behaviour of the samples. As baseline Dynamic Light Scattering at different angles, Small Angle Light Scattering in homodyne configuration and Time Resolved Correlation Spectroscopy will be provided. The implementation of Confocal Depolarised Dynamic Light Scattering for the characterisation of clusters will also be considered. The potential for scientific synergies with direct observations using NASA’s Light Microscopy Module will be fully exploited by the teams. Wherever technical feasible, dedicated cells will be made compatible with both instruments. A third instrument, ‘Vip-Gran’ to investigate granular gases in vibrated cells and stresses in compacted grains was also designed. It will undergo extensive scientific testing on parabolic flights in the coming years. The instruments are developed by European industry under ESA contracts.
Control of Ethylene in Spaceflight Plant Growth Chambers. O. Monje1, 2Space Life Sciences Laboratory, ESC Team QNA, Kennedy Space Center, FL, USA.

Ethylene, a plant hormone, can affect plant growth at very low concentrations (25-50 ppb). Spaceflight plant experiments on the Space Shuttle and on the Mir space station have been compromised by inadvertent exposures of plant material to elevated ethylene concentrations. Therefore, ethylene must be controlled in spaceflight plant growth chambers to avoid leaf epinasty and yield reductions. Ethylene is hard to measure onboard spacecraft and it is typically controlled using engineering controls. Ethylene control can be passive (e.g. filtered with chemicals) or active (e.g. degraded using photocatalytic oxidation). Recently, both passive and active methods were explored for use in the Advanced Biological Research system (ABRS) and in the Advanced Plant Habitat (APH) spaceflight growth chambers. Passive ethylene control using Purafil SP was studied and it was found that Purafil also co-adsorbs carbon dioxide, which may affect the CO2 control subsystem of the chamber. In contrast, an active method using Solgel’s Silica-Titania Composite, a photocatalyst, did not affect CO2 control but it required a source of UV.

Supported by Space Life and Physical Sciences Research and Applications / ISS NASA Research Office.

Examining the CO2 Dependent Relationships in a Membrane Aerated Biological Reactor Treating a Space-Based Wastewater. Dylan Christenson1, Audra Morse1, W. Andrew Jackson1, Karen Pickering2, Daniel Barta3, Kevin Nguyen1, Elizabeth Cummings1. 1Texas Tech University, Lubbock, TX, USA; 2NASA Johnson Space Center, Houston, TX, USA.

In order to enable long term space habitation, sustainable advanced life support systems with minimal reliance on consumables are essential. Water recovery is a fundamental component of these systems, and Membrane Aerated Biological Reactors (MABRs) have been proven to be an efficient and sustainable process for extra terrestrial wastewater recycling applications that can eliminate the need for urine pretreatment and decrease loading on downstream processes. NASA is currently operating biological reactors in an integrated systems test based on a MABR design developed at Texas Tech University (TTU). In support of this test, CoMANDR (Counter-diffusion Membrane Aerated Nitrifying Denitrifying Reactor) was operated for the past year at TTU. The CoMANDR system was used to treat unstabilized wastewater composed of urine, hygiene water, humidity condensate, and laundry water. Influent wastewater values averaged 900 mg-N/L for total nitrogen and 575 mg/L for total organic carbon. Overall, >60% nitrification and >90% organic carbon removal efficiencies were maintained over various operational characteristics and loading scenarios. As part of this effort we evaluated the impact of the CO2 gas concentration on treatment efficiency and pH, two inter-related variables critical for reactor performance. In addition we also performed an evaluation of the microbial population after 1 year of operation. In a MABR, the flux of CO2 through the biofilm into the membrane lumen is controlled by the concentration gradient. When the system is operated at low gas flushing rates, the aqueous phase CO2 concentration can greatly increase due to microbial oxidation of organic matter. This increase leads to a decrease in pH and the subsequent inhibition of ammonium oxidation. Understanding the CO2 dependent relationships within an MABR are essential because the gas flow also impacts the oxygen concentrations within the reactor. The relationships among CO2 transport, production, biofilm activity, and nitrogen transformation and removal efficiency will be discussed in context with the spatial variation in microbial ecology.

The researcher would like to acknowledge Dr. Audra Morse, Dr. Andrew Jackson, and the Water Reclamation Technology group at Johnson Space Center as well as the financial support provided by NASA and the Texas Space Grant Consortium.

Development of a High-Intensity, Variable-Spectra LED Array for Optimized Plant Development in Challenging Environments. David Hawley1, Michael Stasiak1, Jamie Lawson1, Alan Scott2, Per Aage Lysaa1, Mike A. Dixon1. 1Controlled Environment Systems Research Facility, University of Guelph, Guelph, Ontario, Canada; 2COM DEV Ltd., Kanata Ontario, Canada; 3Intravision Group AS, Snaroya Norway.

Plant development can be dramatically influenced by the quality of light present in their environment. Many factors, such as rates of photosynthesis and dry-matter production, synthesis of specific compounds, or time of flowering can be manipulated through the use of specific wavelengths of light. Researchers at the Controlled Environment Systems Research Facility (CESRF) have developed an array of high-intensity, narrow-bandwidth LEDs. The array contains LEDs of nine distinct wavelengths, ranging from short-wavelength UV LEDs to relatively long-wave far-red LEDs. Individually, each wavelength present is sufficient in intensity to drive associated pathways in plants. The intended use for the array is to develop light “recipes” that maintain a plant’s optimum light environment for whatever developmental characteristic is desired. The short term goal at the CESRF with this array is to optimize dry matter accumulation in lettuce and tomato plants for food production in challenging environments. Design considerations for deploying LEDs in this study are presented.

Supported by Natural Sciences and Engineering Research Council (NSERC), Canadian Space Agency and Industry partner COM DEV Ltd.

Off-Vertical Axis Rotational Assessment of Transdermal Scopolamine for Motion Sickness Prophylaxis. Daniel L. Woodard4, Glenn W. Knox2, Scott Wood3, Cathy DiBiase1. 1Bionetics Corporation, NASA-Kennedy Space Center; 2University of Florida Health – Jacksonville, Department of Surgery, Division of Otolaryngology; 3Universities Space Research Association.

Objective: Evaluation of transdermal scopolamine for motion sickness prophylaxis; Study Design: Randomized, prospective double blind. Setting: Vestibular research laboratory; Patients: 12 patients, 7 male, 5 female, ages 21 to 57, normal auditory/vestibular function Intervention(s): Off-vertical axis rotation 20 degrees in the dark after administration of transdermal scopolamine or placebo. Main Outcome Measures: Duration of tolerated off-vertical rotation; subjective symptom reporting during rotation at one-minute intervals on a 0 to 4 scale. Results: Patients treated with transdermal scopolamine had statistically significant improved
tolerance time to off-vertical axis rotation. Reported symptomatology on the 0-3 subjective symptom scale was significantly improved as compared to placebo and was dose-dependent. Conclusions: Off-vertical axis rotation is a useful modality for the evaluation of motion sickness medications. Transdermal scopolamine showed statistically significant dose-dependent effects in mitigating OVAR-induced motion sickness symptomatology and was well tolerated.

Concurrent Session 45: Vertebrates 5
Session Chair: Amir Zeituni, Global Science & Technology, Inc., National Institute of Allergy and Infectious Diseases
Time: Thursday, 4:00 pm – 5:00 pm

[C45.1] Carotid and Femoral Intima Media Thickness Change During Long Term Confinement (Mars 500). P Arbeille, R Provost, N Vincent, A Aubert. Medicine Physiologie Spatiale (UMPS-CERCOM), University Hospital Trousseau, 37044, Tours, France.
CRIP Laboratoire d’informatique, Faculte de Medecine, Paris V, France, University Hospital Gasthuisberg, O&N Lab of Experimental Cardiology, Herestraat 49, KU 3000, Leuven, Belgium.

The objective was to check if 520 days in confinement (MARS 500), may affect the main peripheral arterial diameter and wall thickness and the main vein size. Common Carotid (CC) Femoral artery (FA) Portal vein (PV), Jugular vein (JG), Femoral vein (FV) and Tibial vein were assessed during MARS 500 by echography, performed by the subjects. A hand free volumic echographic capture method and a delayed 3D reconstruction software developed by our lab were used for collecting and measuring the vascular parameters. During the MARS 500 experiment the subjects performed 6 sessions among which 80% of the echographic data were of sufficient quality to be processed. No significant change was found for the Common Carotid, Jugular vein, Femoral artery, Femoral vein, Portal vein, and Tibial vein diameter. CC and FA IMT (intima media thickness) were found significantly increased (14% to 28% P<0.05) in all the 6 subjects, during the confinement period and also at +2 days after the confinement period, but there was no significant difference 6 month later compare to pre MARS 500. The experiment confirm that even untrained to performing echography the subjects were able to capture enough echographic data to reconstruct the vessel image from which the parameters were measured. The increase in both CC and FA IMT should be in relation with the stress generated by the confined environment or absence of solar radiation, as there was no change in gravity, physical activity, nutrition, temperature and air in the MARS 500 module.

Supported by ESA (European space agency) and CNES (French space agency), 2011 grants.

[C45.2] Lower Body Negative Pressure Counters Short-Duration Head-Down-Tilt Induced Elevation in Intraocular Pressure. B.R. Macias, A.R. Hargens, J.H.K. Liu. Departments of Orthopaedic Surgery and Ophthalmology, University of California-San Diego, San Diego, CA, USA.

Recent ophthalmic evaluations of seven astronauts after six-month missions to International Space Station show unexpected vision problems. In addition, lumbar punctures performed in the four astronauts with optic disc edema showed moderate elevations of cerebral spinal fluid pressure after returning to Earth. This Visual Impairment Intracranial Pressure (VIIP) syndrome is likely due to a head-ward body fluid shift that elevates intracranial pressure and intraocular pressure. We hypothesized that a moderate level of lower body negative pressure (LBNP) would counter fluid shift induced elevations in intraocular pressure (IOP). Eight normal healthy non-smoking volunteers participated in this study (mean age: 36 years). Right and left IOP (Reichert Pneumatonometer), arm blood pressure, and heart rate were measured during the last minute of each testing condition. Subjects were positioned supine (5 mins), sitting (5 mins), 15-degrees whole body head-down tilt (HDT) (5 mins) and ten minutes of HDT with LBNP (25 mmHg). The order of HDT and HDT+LBNP tests were balanced. The right and left IOP values were averaged and used for statistical analysis. Data are presented as mean ± standard deviation. The change from supine was calculated for each variable and analyzed by ANOVA. Significance was accepted when p<0.05. IOP significantly decreased from supine to sitting posture by 2.5 ± 0.8 mmHg, and increased by 1.6 ± 2.5 mmHg from supine to the HDT position. LBNP during head-down-tilt significantly lowered IOP to supine levels (difference from supine, 0.15 ± 0.7 mmHg). Mean blood pressure and heart rate did not change significantly across all conditions. These data demonstrate that short duration exposures to HDT and LBNP significantly alter IOP. Therefore, spaceflight countermeasures that simulate hydrostatic pressure gradients may mitigate vision problems. Future studies will include non-invasive measures of intracranial pressure in similar experimental conditions.

BRM supported by NSBRI postdoctoral fellowship and study funded by NASA grant #NNX13AJ12G (to ARH).


With increased explorations into the outer realms of space, astronauts are put under new and unexplored stresses. Although there has been significant research conducted to investigate the effects of microgravity on many human biological mechanisms, there has been very little research conducted to better understand the effects of microgravity on the Cori cycle. The Cori cycle is responsible for the conversion of lactic acid in the muscle to pyruvate by way of the liver, which causes the production of the Adenosine triphosphate (ATP). ATP is used by muscle cells as an energy source for muscular contraction during muscular activity. In order to study this process we observed the reaction between Pyruvate and Nicotinamide adenine dinucleotide (NADH) in the presence of lactate dehydrogenase (LDH) to form Lactate and NAD+. Using a spectrophotometer, we measured the change in absorbance as NADH was consumed while the reaction occurred. Microgravity measurements were very recently made on board NASA’s microgravity research aircraft as part of their Reduced Gravity Education Flight Program. This highly competitive program provides select undergraduate students the opportunity to fly experiments on their “O-g” aircraft. Flight data will be compared to ground truth measurements of the reaction made in 1-g. We present the findings of our investigation as well as future plans.

The Weightless Lumbrees research team is supported by grants from the North Carolina Space Grant consortium and UNCP Research Initiative for Scientific Enhancement (RISE).
[C46.1] Distribution and Ordering of Fine Particles in Cylindrical Discharges under Gravity. H. Totsuji, K. Takahashi, S. Adachi, C. Totsuji, M. Tonouchi. 1JAXA/ISAS, Tsukuba, Japan; 2Kyoto Institute of Technology, Kyoto, Japan; 3Kogakuin University, Tokyo, Japan. The distribution and ordering of micron-sized fine particles in cylindrical discharges (positive column) are analyzed by theory and simulations and compared with experiments both under gravity and microgravity (parabolic flights).

In the case of fine particles of one species, drift-diffusion equations show that particles are distributed around the axis and lead to the conditions for non-existence of central voids in terms of plasma density, the gas pressure, and other parameters. These equations are also applied to the case of two species of particles with different radii; in the typical distribution, smaller particles are located within the void formed by larger particles. Theoretical analyses are supplemented by particle simulations which give microscopic structures of particle clouds such as given in Ref. 1. A theoretical justification and the limit of applicability of these equations are also derived on the basis of statistical physics.

When the effect of gravity (acting perpendicularly to the axis) is taken into account, we naturally lose the cylindrical symmetry of distributions. Utilizing the electrostatic potential theoretically obtained for the case of microgravity, the deformations of distributions are analyzed by numerical simulations.

Results of theory and simulations are compared with experiments both under gravity and microgravity. Similarities and differences are pointed out and discussions on experimental parameters are given. Ref. 1. H. Totsuji and C. Totsuji, Phys. Rev. E 84, 015401(R)(2011). Supported as an activity of JAXA/ISAS WG.

[C46.2] Development and application of particle image velocimetry for PlasmaLab. E. Thomas, Jr., T. Hall, J. Shaw, U. Konopka, C. A. Knapke, H. M. Thomas, and G. E. Morfill. 1Physics Department, Auburn University, Auburn, AL, USA, 2Department of Physics, The University of Texas at Austin, Austin, TX, USA, 3Max-Planck-Institute for extraterrestrial physics, Garching, Germany.

“PlasmaLab” is a next-generation microgravity experiment dedicated to the study of complex (dusty) plasmas. Complex plasmas are four-component plasma systems consisting of ions, electrons, neutral atoms, and charged, micron-sized particles (i.e., “dust”). Because the microparticles are charged, they freely interact with the background plasma. However, due to the large dust grain mass, compared to the ions and electrons, the temporal and spatial scales of a complex plasma become stretched so that a broad range of digital imaging techniques can be used to analyze these systems. Particle image velocimetry (PIV) is a fluid measurement technique that can be used to measure particle transport, instabilities, and the velocity space distribution function of the microparticle component of the plasma. This presentation will discuss the application of PIV to parabolic flight measurements using the cylindrical PlasmaLab chamber. A comparison will be made between the flight data and ground-based experiments that seek to extend the PIV technique.

This work is supported by funding from NASA (NNX10AR53G), the Jet Propulsion Laboratory (JPL-RSA 1471384) and DLR/BMWi under contract 50WM0700.

[C46.3] Transport Measurements in Dusty Plasmas under Microgravity Conditions. John Goree and Bin Liu. Dept. of Physics and Astronomy, The University of Iowa, Iowa City, Iowa, USA.

A dusty plasma is an exceptionally soft substance made of charged microspheres that are electrically confined in a plasma containing electrons, ions and neutral gas. Depending on their charges and kinetic energy, the microspheres tend to self-organize in a structure that is like a crystalline lattice or a liquid. For studying the physics of liquids, dusty plasmas are valuable because they provide an experimental system that allows direct imaging at the particle level. Among the many phenomena that can be studied, here we focus on transport including diffusion and shear viscosity. Coefficients for diffusion and viscosity have been measured for liquid-phase dusty plasmas in laboratory experiments, which we review. We then assess the requirements for measuring these coefficients in a microgravity experiment. Assuming typical PK-4 experimental parameters, we use computer simulations of particle motion to generate time series data for particle positions and velocities, which are the same form of data as is generated from experimental video images. The image analysis uses an optimized particle tracking velocimetry (PTV) method, which we review. For conditions with no flow, we compute the viscosity and diffusion coefficients using the Green-Kubo and mean-square displacement methods, respectively. We assess the experimental requirements for camera frame rate and thickness of the illumination laser sheet.

This work is supported by NASA.

Concurrent Session 47: Combustion 4 – Microgravity Fire Safety and Flammability (Part II)
Session Chair: Sandra Olson, NASA Glenn Research Center
Time: Thursday, 4:00 pm – 5:00 pm

[C47.1] Thickness and Fuel Preheating Effects on Material Flammability in Microgravity from the BASS Experiment. Paul Ferkul, Sandra L. Olson, Fumiaki Takahashi, Makoto Endo, Michael C. Johnston, James S. T’ien. 1National Center for Space Exploration Research; 2NASA Glenn Research Center; 3Case Western Reserve University.

The Burning and Suppression of Solids (BASS) experiment was performed on the International Space Station. Microgravity combustion tests burning thin and thick flat samples, acrylic spheres, and candles were conducted. The samples were mounted inside a small wind tunnel which could impose air flow speeds up to 40 cm/s. The wind tunnel was installed in the Microgravity Science Glovebox which supplied power, imaging, and a level of containment. The effects of air flow speed, fuel thickness, fuel preheating, and nitrogen dilution on flame appearance, flame growth, and spread rates were determined in both the opposed and concurrent flow configuration. In some cases, a jet of nitrogen was introduced to attempt to extinguish the flame.

Microgravity flames were found to be especially sensitive to air flow speed in the range 0 to 5 cm/s. The gas phase response is much faster compared to the solid and so the flow speed is...
changed, the flame responds with almost no delay. At the lowest speeds examined (less than 1 cm/s) all the flames tended to become dim blue and very stable. However, heat loss at these very low convective rates is small so the flames can burn for a long time. At moderate flow speeds (between about 1 and 5 cm/s) the flame continually heats the solid fuel resulting in an increasing fuel temperature, higher rate of fuel vaporization, and a stronger, more luminous flame as time progresses. Only the smallest flames burning acrylic slabs appeared to be adversely influenced by solid conductive heat loss, but even these burned for over 5 minutes before self-extinguishing. This has implications for spacecraft fire safety since a tiny flame might be undetected for a long time. While the small flame is not particularly hazardous if it remains small, the danger is that it might flare up if the air convection is suddenly increased or if the flame spreads into another fuel source. This work was supported by the NASA Space Life and Physical Sciences Research and Applications Division (SLPSRA).

[C47.2] Flame Spread over a Thin PMMA Sheet in Low Oxygen Level under Microgravity Condition. S. Takahashi¹, T. Ebisawa¹.

¹Department of Mechanical Engineering, Gifu University, Gifu, Japan.

The behavior of the flame spread over a thin PMMA sheet in low oxygen level was investigated in parabolic flight experiments. The PMMA sample was 6cm in length and 125 micro-m in thickness; it was set in the center of wind tunnel that could provide mild flow whose velocity could be varied from 0 to 25 cm/s. The extinction limit was obtained from the experimental results and it was compared with the prediction by scale analysis method. In low oxygen level under microgravity, the relative velocity of the ambient flow could be much lower than that of buoyant flow, which is typically 30-40 cm/s. When the relative opposed flow velocity was near 10cm/s, the minimum oxygen concentration in which flame was able to propagate on the sample became lower than that for downward spread in normal gravity, namely limiting oxygen index (LOI). The minimum oxygen concentration extended to 15.2% whereas the LOI for PMMA was 17.3 %. If the relative opposed flow velocity was further decreased, the minimum oxygen concentration increased in turn. These trends were explained with the result of the scale analysis. Then, in order to clarify the effect of thermal properties of the ambient gas, we used carbon dioxide instead of nitrogen as the diluent gas. In carbon dioxide balance, the downward spread was not achieved under normal gravity for 21 % oxygen concentration. It meant that the PMMA was not flammable in 21 % oxygen concentration with carbon dioxide balance. However, in the mild flow under microgravity, the steady flame spread was observed when the relative opposed flow was near 10 cm/s in 21 % oxygen concentration. When carbon dioxide was used as the diluents, robust flame was observed even near a quiescent condition in contrast with the case of nitrogen balance. It was due to the small thermal diffusivity and re-absorption effect of carbon dioxide. Supported by Preparations for the Kibo Second Phase Utilization, JAXA.

[C48.1] Coarsening of Wet Aqueous Foams in Microgravity. D.J. Durian¹ and P. Tin². ¹University of Pennsylvania, Department of Physics and Astronomy, Philadelphia, PA, USA; ²NASA Glenn Research Center, Cleveland, OH, USA.

The objective of the FOAM-C Flight Experiment is to understand how liquid-based foams evolve with by a combination of gas diffusion across soap films and by film rupture. Baseline knowledge is restricted to very dry foams, since gravitational drainage of the liquid between bubbles increases rapidly with liquid content and can even cause bubble convection. Since gas and liquid cannot be density matched, prolonged microgravity conditions are required to eliminate these effects and hence permit wet foams to significantly evolve without interference. The approach is to measure bubble sizes in the bulk by diffusely transmitted light and at the surface by optical microscopy. Bubble rearrangement dynamics will be measured by diffusing-wave spectroscopy (DWS) and speckle-visibility spectroscopy (SVS). This is to be done for a variety of foaming systems, with different surfactants and particulate additives. The resulting knowledge to be gained of foam microstructure and dynamics will be additionally useful as a fundamental basis for understanding foam rheology. Issues of foam fluid stability and rheology are furthermore crucial for multiphase flows and separations, for firefighting foams, and to provide guidance for the production of polymeric and metallic foams as lightweight structural materials. The status of the flight experiment, as well as recent results from supporting ground-based experiments, will be reviewed. The Project Scientist is Dr. Padetha Tin (Glenn Research Center).

Supported by supported by NASA Microgravity Fluid Physics Grant NNX07AP20G.

[C48.2] Phase separation of colloid-polymer mixtures in microgravity: BCAT to ACE. Peter J. Lu. Department of Physics and SEAS, Harvard University, Cambridge MA 02138 USA.

We present the results of a series of experiments looking at phase-separation in colloid-polymer mixtures approaching the critical point. Using photography to characterize the spatio-temporal dynamics of these systems, we observe spinodal decomposition and coarsening, at very slow rates not easily accessed on earth and therefore not commonly seen in other systems. I discuss recent progress in this series of experiments, how this connects with upcoming investigations in future BCAT experiments with CASIS, and the upcoming microscopy-based ACE efforts. We gratefully acknowledge funding from NASA (NNX08AE09G, NNX08AE09G S11, NNC08BA08B), the NSF (DMR-1006546), and the Harvard MRSEC (DMR-0820484).
The Advanced Colloids Experiment (ACE) Science Overview.


The LMM is a microgravity microscope facility designed to allow scientists to process, manipulate, and characterize colloidal samples in microgravity where the absence of gravitational settling and buoyancy allows for the unique ability to study colloids. The LMM is being built-up in stages, with the availability of the Light Microscopy Module (LMM) on ISS. To meet these goals, the ACE project comprises a series of experiments that will probe the interfacial and hydrodynamic behavior of freely suspended liquid crystal (FSLC) films in space. These are the thinnest known stable condensed phase structures, making them ideal for studies of fluctuation and interface phenomena. The experiments seek to verify theories of coarsening dynamics, hydrodynamic flow, relaxation of hydrodynamic perturbations, and hydrodynamic interactions of a near two-dimensional structure. The effects of introducing islands or droplets on a very thin bubble will be studied, both as controllable inclusions that modify the flow and as markers for the non-equilibrium coarsening dynamics of island emulsions.

The ACE experiment is being conducted on the International Space Station (ISS) using the Light Microscopy Module (LMM) in the Fluids Integrated Rack (FIR).

An overview of the work to date will be discussed and future plans and opportunities will be highlighted.

The LMM is a microgravity microscope facility designed to allow scientists to process, manipulate, and characterize colloidal samples in microgravity where the absence of gravitational settling and particle jamming enables scientists to study such things as:

- The role that disordered and ordered-packing of spheres play in the phase diagram and equation of state of hard sphere systems,
- Crystal nucleation and growth, growth instabilities, and the glass transition,
- Gelation and phase separation of colloid polymer mixtures,
- Crystallization of colloidal binary alloys,
- Competition between crystallization and phase separation,
- Effects of anisotropy and specific interactions on packing, aggregation, frustration and crystallization,
- Effects of specific reversible and irreversible interactions mediated in the first case by hybridization of complementary DNA strands attached to separate colloidal particles,
- “Lock and key” interactions between colloids with dimples and spheres which match the size and shape of the dimples,
- Finding the phase diagrams of isotropic and interacting particles,
- New techniques for complex self-assembly including scenarios for self-replication,
- Critical Casimir forces,
- Biology (real and model systems); plants, c. elegans, tissue, m. etc.

By adding additional microscopy capabilities to the existing LMM, NASA will increase the tools available for scientists that fly experiments on the ISS enabling scientists to observe directly what is happening at the particle level. Presently, theories are needed to bridge the gap between what is being observed (at a macroscopic level when photographing samples) with what is happening at a particle (or microscopic) level. What is happening at a microscopic level will be directly accessible with the availability of the Light Microscopy Module (LMM) on ISS. To meet these goals, the ACE experiment is being built-up in stages, with the availability of confocal microscopy being the ultimate objective.

Supported by NASA’s Physical Sciences Research Program, ESA/ESTEC, and the authors’ respective governments.

The Observation and Analysis of Smectic Islands in Space (OASIS) project comprises a series of experiments that will probe the interfacial and hydrodynamic behavior of freely suspended liquid crystal (FSLC) films in space. These are the thinnest known stable condensed phase structures, making them ideal for studies of fluctuation and interface phenomena. The experiments seek to verify theories of coarsening dynamics, hydrodynamic flow, relaxation of hydrodynamic perturbations, and hydrodynamic interactions of a near two-dimensional structure. The effects of introducing islands or droplets on a very thin bubble will be studied, both as controllable inclusions that modify the flow and as markers for the non-equilibrium coarsening dynamics of island emulsions.

The OASIS flight hardware is being designed based on proven, ground-tested and aircraft-tested experimental hardware. The flight hardware will operate inside the Microgravity Science Glovebox (MSG). Each liquid crystal sample will be placed in separate sample containers, referred to as Bubble Chamber Inserts that are housed in a larger Bubble Chamber Enclosure. The Bubble Chamber Enclosure container includes all of the hardware necessary to create, inflate, illuminate, position, manipulate, and observe liquid crystal bubbles and islands. A Macro-camera observation system will consist of the MSG provided camera with COTS lens attachment and a microscope system, housed in the Optics/Illumination assembly, will be employed to study the 2D hydrodynamic and diffusion behavior of the liquid crystals. A dedicated data acquisition and control unit controls the hardware and the entire system will be remotely commanded from the ground. In this report, a detailed evaluation and experimental results of OASIS engineering apparatus that was used to test out the engineering hardware and future works on the study of liquid crystal thin films in microgravity conditions will be presented.

The authors acknowledge DLR for the continuous support of Co-I Ralf Stannarius under grant 50WM1127 as well as the support under NASA Grant NNX07AE48G.
[C49.1] Numerical investigation for the thermocapillary flow observed in “Saturday-Morning-Science” conducted by Dr. Donald Pettit. T. Yamamoto¹, Y. Takagi¹, Y. Okano¹, and S. Dost¹.

¹Department of Materials Engineering Science, Osaka University, 1-3 Machikaneyama, Toyonaka, Osaka 560-8531, Japan; ²Crystal Growth Laboratory, University of Victoria, Victoria, British Columbia, V8W 3P6, Canada.

NASA astronaut Dr. Donald Pettit carried out a series of simple science experiments on the International Space Station (ISS) in 2003 and 2012 through a program called “Saturday Morning Science” In one of the experiments of 2003, he reported a thermocapillary flow in a thin water film formed in a circular ring. The flow developed in the film was towards the heated section of the ring, which is opposite to the usual thermocapillary flows observed on Earth (hot to cold). In the experiment conducted in 2012 however, thermocapillary flows were observed in both directions (towards both cold and hot sections). To shed light on these observations and also to understand the mechanism governing the flow direction, we have carried out a numerical simulation.

The simulation was conducted using the OpenFOAM package. In the simulation, the deformation of the free surfaces due to the thermocapillary flow was neglected. Shapes of the static free surfaces were determined in two ways: one by using the approximate Young-Laplace equation, and the other by considering an arbitrary meniscus shape. The wire/water interface was assumed to be flat in both cases. To reduce computational cost, diameter of the water film was selected smaller: 10mm. The film thickness was taken as 0.2 mm.

The simulation results show that the water film shape is the key factor in determining the flow direction. When the water film volume is large leading to a convex water film shape, the developed flow is towards the heated region. However, when the film volume is smaller and consequently the water film surfaces are concave, the developed flow is towards the cold section. Results also show that, when the water film is concave and the arbitrary meniscus shape is very sharp, the flow is towards the heated section. As a conclusion we may state that the shapes of free surfaces and meniscus determine the direction of developed flows.

This research was financially supported by Grant-in-Aid for Scientific Research (B) (no. 22360343) from the Ministry of Education, Culture, Sports, Science, and Technology of Japan, and by Collaborate Research Program for Young Scientists of ACCMS and IMIC.

[C49.2] Influence of Liquid Bridge Shape on the Oscillatory Marangoni Convection under Micro and Normal Gravity. T. Yano¹,², K. Nishino¹, I. Ueno¹, S. Matsumoto¹, H. Kawamura¹, Yokohama National University, Japan; ²Research Fellow of Japan Society for the Promotion of Science, Japan; ³Tokyo University of Science, Japan; ⁴Japan Aerospace Exploration Agency, Japan; ⁵Tokyo University of Science, Suwa, Japan.

Marangoni convection is a flow that is driven by the surface tension gradient along the liquid-gas interface, and this flow plays an important role in microgravity and in small-scale flows because the surface force becomes dominant over the body force. A series of microgravity experiment on the Marangoni convection in liquid bridge (LB, hereafter) has been carried out on “Kibo” of the International Space Station (ISS). LBs of high Prandtl number fluids are formed between two coaxial disks heated differentially. LBs are 30 or 50mm in diameter and up to 62.5mm in length. Such large LBs can be formed only in a long term microgravity on ISS. The Marangoni convection in the LB changes to an unsteady 3-D oscillatory state when the temperature difference between the disks reaches the critical value. It is known that the onset condition of oscillatory Marangoni convection depends on various factors (e.g. physical properties of working fluid, ambient gas conditions, LB geometry), and the purpose of the present study is to examine the influence of LB shape on the conditions of the transition. From the previous studies on the ground, it is known that the critical temperature difference show a clear peak at VR=0.9 for AR=0.5 and that the azimuthal mode number of oscillation changes from 1 to 2 at this peak. Here, AR (aspect ratio) and VR (volume ratio) stands for the ratio of the disk distance to the disk diameter and the ratio of the liquid volume to the cylindrical volume between the disks, respectively. These non-dimensional parameters are widely used for specifying the LB shapes. The present space experiments have revealed that the LB shape also affects the instability and oscillation mode but the peak position shifts to VR=0.55 and the observed azimuthal mode number remains unity for AR=0.5. For AR=0.4, however, the change of azimuthal mode number with VR is observed, suggesting that the LB shape dependency of instability and oscillation mode of Marangoni convection is different between ground and space experiments.

Supported by JSPS KAKENHI (Grant-in-Aid for Science Research (B), 21360101, 24360078 and Grant-in-Aid for JSPS Fellows, 2527228).

[C49.3] Thermocapillary-Driven Flow in a Thin Free Liquid Film under Heat Transfer with Ambient Gas. Dr. Limnukhawat³, and I. Ueno², ³Division of Mechanical Engineering, School of Science & Technology, Tokyo University of Science, Noda, Chiba, Japan; ²Department of Mechanical Engineering, Faculty of Science & Technology, Tokyo University of Science, Noda, Chiba, Japan; ³Research Institute for Science & Technology (RIST), Tokyo University of Science, Noda, Chiba, Japan.

This research focuses on the effect of heat transfer over the free surface on the instabilities of a thermocapillary-driven flow in a thin free liquid film by numerical approaches. A transition from a two-dimensional steady flow to three-dimensional oscillatory ones known as hydrothermal waves (HTW) can be observed when the temperature difference induced within the liquid film exceeds a certain critical value. The HTWs in free liquid films were discovered by experiments and numerical simulations by Ueno & Torii (Acta Astronautica 2010). This research has been inspired by the work on a hydrothermal wave instability in a thin liquid film with a single free surface done by Smith & Davis (JFM 1983). Smith & Davis (1983) predicted that the changes in Biot number Bi lead to transitions in the critical values and the characteristics of the HTWs. In the present research we perform numerical simulations taking ambient air regions into consideration to realize a natural inconstant Bi distribution over the free surfaces. We also include the heat transfer between the heating/cooling plates and the ambient air in the domain varying the depth of the ambient air region in order to observe the characteristics of the ambient air flow structure leading to a more complicated heat transfer conditions. 0.65 and 5-cSt silicone oils’ properties are employed as high-Prandtl-number test fluids.

Results of calculations without heating/cooling plates show
changes in angle of propagation of the HTW with various depths of the ambient air region. Moreover we indicate an existent of a critical depth of the ambient air region where a switch between heat loss and heat gain over the free surfaces takes place. As for the results of the calculations containing heating/cooling plates, we observe spatial shifts in the HTW’s structures when there exist changes in the Bi distribution. We will be discussing how the flow structures and heat transfer characteristics in various depths of the ambient air region (with and without heating/cooling plates) influence the flow structure of the liquid film.

[C49.4] GeoFlow experiment series: Spherical shell convection in self-gravitating force field in microgravity environment of ISS. B. Futterer1, C. Ebbers2, F. Zaussinger1, P. Chossat3, E. P. Weller4, D. Breuer3, F. Feudel4, I. Mutabazi5, L. Tuckerman6,1 Brandenburg University of Technology Cottbus-Senftenberg (Ge), 2CIRM Marseille (Fr), 3University of Leeds (UK), 4University of California-Davis (USA), 5University of Maryland (USA), 6PMMH-ESPCI Paris.

In fluid dynamics research complementary approaches are often used, (i) theory determines basic concepts, (ii) numerical simulation checks modeling, (iii) experimental measurement captures non-linear effects without analytical and numerical simplifications. This is a fundamental idea of the GeoFlow experiment series: to support geoscientifically motivated convective fluid dynamics with basic real fluid physics experiments [1-4]. A very specific focus of GeoFlow is the Rayleigh-Bénard system in experimental spherical shell geometry and the influence of several driving mechanisms (thermal drive, rotational aspects, and temperature dependence of physical properties). Laboratory experiments involving such a configuration are complicated by the fact that gravity is then vertically downward rather than radially inward. One alternative is to conduct the experiment in microgravity. Imposing a voltage-difference between the boundaries, and using a dielectric insulating liquid can further create a radial force. The first such experiment is performed by [5] using a hemispherical shell, and had been accomplished on the space shuttle Challenger in May 1985. Our successor experiment GeoFlow, not only involved a full shell instead of a hemisphere, but was also designed to be performed on the International Space Station, where considerably longer flight times are possible [6]. Two versions of GeoFlow had been accomplished: GeoFlow I, involving an essentially constant viscosity fluid and rapid rotation, was processed from August 2008 to January 2009 [7]; GeoFlow II, involving a fluid with temperature-dependent viscosity, was processed from March 2011 to May 2012 [8], now followed by GeoFlow III starting in December 2012. The purpose here is to present the evolution of the project, to summarize the specific results (e.g. [9]) and to give an outlook to further missions.

[C49.5] Flow Transition of Thermocapillary Convection in Larger Liquid Bridge with High Prandtl Number. S. Matsumoto1, K. Omura2, and S. Yoda3. 1Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency, 2Graduate School of Systems and Information Engineering, University of Tsukuba, Japan.

Thermocapillary flow occurred in liquid bridge configuration still has several problems to be solved. Critical condition and mechanism on oscillatory flow transition, transition process from steady toward turbulent flows are now trying to be clarified. Recently, we have got a laboratory in the International Space Station (ISS). It provides the long and high quality microgravity condition. Utilizing this laboratory, we can realize the larger liquid bridge formation to observe the detailed flow and temperature field. In order to investigate the flow transition process, we performed an experiment under microgravity condition onboard the ISS. The liquid bridge with 50 mm in diameter was formed between solid disks. Its length was varied up to 62.5mm. Silicone oil with viscosity of 5 and 10 mm²/s was employed as working fluid, which Prandtl number was 68 and 113, respectively. After the formation of liquid bridge, temperature difference between both ends of liquid bridge was imposed to generate convection. By changing the temperature difference, the driving force of convection could be controlled. The convection would be transit from steady to oscillatory, chaotic and finally turbulent flows with increasing the driving force. The flow field was observed by ultrasonic velocity profiler. The two transducers were embedded in cooling disk. Ultrasonic pulse irradiated toward the liquid bridge, and echoes were received by the transducers. The special and velocity information were taken from signal processing. Velocity profile and energy spectral density could be obtained especially when the convection became stronger. The characteristic of oscillatory and chaotic flows would be discussed.

Concurrent Session 50: Complex Fluids 3
Session Co-Chairs: Olivier Minster (European Space Agency) and Paul Chaikin (New York University)
Time: Friday, 8:00 am – 10:00 am

[C50.1] Translation, Manipulation, and Assembly with Linear Optical Trapping. D.W.M. Marr, Chemical and Biological Engineering Department, Colorado School of Mines, Golden, CO, USA.

Providing a relatively simple but effective approach, we employ inexpensive laser diode bars to create distributed linear optical traps suitable for integration with microfluidic systems. Such platforms provide an ideal environment to explore the combination of hydrodynamic and optical forces for applications in small particle manipulation. In this brief overview, we will discuss three studies where both cells and colloidal systems are investigated. In the first, we take advantage of the laminar nature of microfluidic flows combined with a linear optical trap to translate particles between streamlines. This approach can be used to efficiently separate and isolate single colloids or cells for subsequent manipulation or investigation. In the second, we note that cell mechanical properties are a useful indicator of cell health. Differences in cell deformability between disease states have been demonstrated in cases such as cancer, malaria, and sickle cell anemia using a variety of bulk and individual-cell measurement techniques. The exploitation of this promising biomarker in population-based studies, however, has been greatly limited by the low measurement throughput of available methods. By combining optical forces and hydrodynamic...
flows, we show how cell deformation measurements can be done on individual cells and with good throughput. Finally, we will demonstrate how this unique combination of forces can be used for the assembly of colloidal systems. In this, particles can be drawn into anisotropic geometries in a continuous fashion, providing a route towards high throughput fabrication.


There is a keen interest in the microstructure and dynamics of colloidal gels because of their relevance to providing long-term mechanical stability against the bulk separation of liquid droplets dispersed in these gels. While there has been significant investigation into the microstructure and dynamics of colloidal gels composed of monodispersed colloids, many practical applications employ colloidal gels composed of complex mixtures of different size colloidal particles. Previous work with polymer polydispersity showed stunning differences in the collapse rate of depletion gels. In this work, we probe the effect from colloid polydispersity on their microstructure and dynamics. In particular, we show the unexpected behavior of depletion gels composed of equal numbers of 1.8- and 2.2-micron colloidal spheres. Specifically, despite the relatively modest size difference and therefore modest difference in attraction, large particles disproportionately aggregate into the gel strands while the small particles diffuse freely. The microgravity environment afforded by the International Space Station and emerging Fluorescence Microscopy capabilities available through the ACE Program at NASA provide the critical elements for tracking these long-time scale changes in the system.

[C50.3] Competition Between Phase Separation and Crystallization in Attractive Colloids. B.J. Frisken, A.E. Bailey, G. Espinosa, J. Sabin. Department of Physics, Simon Fraser University, Burnaby BC Canada.

This presentation will focus on results from recent experiments on earth and on the International Space Station investigating the interplay between phase separation and crystallization in samples prepared in the three-phase region (gas-liquid-crystal) of the phase diagram of a colloid-polymer mixture. On earth, our samples first separate into a colloid-rich phase and a colloid-poor phase, with crystals forming in the colloid-rich phase. The denser phases sediment as expected. In microgravity, photographic images obtained in the BCAT-5 experiment reveal phase separation with crystal formation in the denser phase, where the phase separation continues normally until the dominant length scale is about 25% of the cell thickness, at which point both phase separation and crystal growth are arrested before macroscopic phase separation can occur. We propose that this arrest occurs because the surface tension is not sufficient to overcome the stiffness of the crystalline network that forms in the liquid phase.

Supported by the Canadian Space Agency.

[C50.4] Aging and Restructuring of Depletion Gels. R. Piazza1, S. Buzzaccaro2, E. Secchi2, and Luca Cipelletti2. 1Department of Chemistry, Material Science and Chemical Engineering, Politecnico di Milano, Italy, 2Laboratoire des colloïdes, verres et nanomatériaux, Université Montpellier 2, France.

When the attractive forces induced by the presence of a high molecular weight additive acting as depletant become strong enough, a colloidal suspension undergoes a liquid—liquid (L-L) phase separation. As for simple liquid mixtures, a colloid suddenly brought within the L-L miscibility gap undergoes a spinodal decomposition process, consisting of phase separation followed by a progressive coarsening of the two phases. However, if the depletion forces are short-ranged, the spinodal decomposition usually gets arrested by the formation of a colloidal network, namely, of a disordered colloidal solid with a gel-like structure.

We present a detailed investigation of the phase diagram of depletion gels and of their restructuring in time under gravitational stress, following over time the concentration profile, the local settling velocity, and the microscopic dynamics by means of novel optical correlation methods, which allow to investigate Brownian dynamics still retaining the imaging capability of video microscopy. Depending on particle concentration and interparticle attraction strength, the gels show two main kinds of settling behavior. At low relative particle concentration and interaction strength, the settling kinetics involves an initial latency stage, followed by a rapid collapse where disconnected clusters fall and pile up at the bottom of the cell, forming a cake that slowly consolidates. At high enough particle concentration and interaction strength, a continuous creeping sedimentation. The detailed settling kinetics of these gels shows some peculiar and unexpected features that are rather new in sedimentation studies. This investigation, which extends a preliminary study [1], is of particular interest in relation to microgravity studies, where gel restructurings is expected to show rather different features.


[C50.5] Colloidal aggregation in microgravity by critical Casimir forces. T. A. Nguyen1, M. A. C. Potenza2, A. Manca2, G. H. Wegdam1 and P. Schall1. 1Van der Waals Zeeman Institute, University of Amsterdam, Science Park 904, 1098 XH Amsterdam, The Netherlands, 2Department of Physics, University of Milan, via Celoria 16, I-20133 Milan, Italy.

Colloids - particles of a few nanometers to a few micrometers suspended in a solvent - are not only abundant in everyday life, but also present the perfect building blocks for making nano-scale structures. Recent years have witnessed exciting progress in the control of particle interactions. This control opens the door to build new complex nanostructures. We use novel critical Casimir forces to study the attractive strength dependent assembly of colloids with and without gravity. Suspended in binary solvents, the particles exhibit attractive potentials that are set precisely by temperature. By using new, anisotropic particles with tailored hydrophobic/hydrophilic surface patches, we realize specific directed bonds analogous to that of molecules. We study the self-assembly of these new, complex-interacting particles by real-space microscopy and near field scattering. I will give an overview over the critical Casimir assembly of colloidal structures, and present new criticality results obtained on the assembly of simple spherical particles.

Supported by the Foundation for Fundamental Research on Matter (FOM), and the Netherlands Organization for Scientific Research (NWO).
I will discuss findings from recent experiments with colloidal suspensions that employ temperature-sensitive microgel particles to study colloidal glasses [1] and crystals. In particular, the role of frustration and quenched disorder in driving the transformation of a crystal into a glass will be discussed [2]. Frustration is induced in crystals of large particles via the addition of smaller particle dopants, and the crystal-glass transition is measured to differ from the liquid-glass transition in quantitative and qualitative ways. Specifically, the crystal-glass transition bears structural signatures similar to those of the crystal-fluid transition: at the transition point, the persistence of orientational order decreases sharply from quasi-long-range to short-range, and the orientational order susceptibility exhibits a maximum. The crystal-glass transition also features a sharp variation in particle dynamics: at the transition point, dynamic heterogeneity grows rapidly, and a dynamic correlation length-scale increases abruptly. This investigation and related experiments will be described.

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Concurrent Session 51: Combustion 5 – Droplet Combustion (Part II)

Session Co-Chairs: Dennis Stocker and Vedha Nayagam, NASA Glenn Research Center

Time: Friday, 8:00 am – 10:00 am

[C51.1] Observations from FLEX - CO₂ Diluent Exchange Tests.

Michael C. Hicks¹, Daniel L. Dietrich¹, Vedha Nayagam¹, and Forman A. Williams¹. ¹NASA Glenn Research Center (GRC), ²National Center for Space Exploration Research (NCSER), ³Department of Mechanical and Aerospace Engineering, University of California at San Diego, USA.

A series of tests, performed as a part of the Flame Extinction (FLEX) experiment on the ISS, investigates droplet burning behavior in atmospheres where CO₂ is exchanged, to varying extents, with N₂ while O₂ is maintained at 21% during the makeup of the combustion chamber’s test atmosphere. Results are reported for both sooting (n-heptane) and non-sooting (MeOH) fuels, in the context of the diluent’s radiative participation, for test pressures of 1 atm and 3 atm. Comparisons of droplet burning rates, flame stand-off distances, and radiant heat loss are made between these CO₂ Diluent Exchange (CO₂-DEx) environments and Air at 1 atm. The discussion of the FLEX CO₂-DEx flight data is further supplemented by results from earlier tests performed in the Zero Gravity Facility (ZGF) at the NASA Glenn Research Center. It is shown that with increasing amounts of CO₂ sooting is significantly reduced and the radiative extinction threshold, as determined by the droplet’s initial diameter, D₀, is altered. Additionally, at elevated pressures the characteristic low-temperature burning regime, which typically follows radiative extinction for the alkane fuels and which was reported in earlier work [Nayagam et al., 2012], will sometimes transition between high-temperature and low-temperature burning regimes until the fuel is completely consumed. This transition between burning regimes is marked by sudden and brief reappearances of a high-temperature flame following protracted periods when the droplet is burning in the low-temperature regime and there is no visible flame.

Supported by the Life and Physical Sciences Division of the NASA Human Exploration and Operations Mission Directorate, HEOMD.

[C51.2] Effectivity of Xenon as Fire Suppressant under Microgravity Combustion Environment. M.E.A. Fahd¹, F.L. Dryer² and T.I. Farouk¹, ¹. ¹Department of Mechanical Engineering, University of South Carolina, Columbia, SC, USA. ²Department of Mechanical and Aerospace engineering, Princeton University, Princeton, NJ, USA.

Since 2009, the Flame Extinguishment (FLEX) program on board the International Space Station has been developing fire-safety protocols via microgravity droplet combustion experiments. A wide variety of hydrocarbon fuels (alcohols, alkanes) under varied environmental condition has been studied. One of the important focus has been to identify suppressants that are effective under ‘zero’ gravity conditions. Therefore, study on the influence of diluents on microgravity combustion and subsequently on flame extinction characteristics can shed lights on fire extinguishment phenomena. In this study, numerical simulations have been conducted to investigate the combustion and extinction characteristics of isolated methanol droplets burning in a xenon enriched environments. For comparison, identical conditions in argon diluent were also studied. The study was conducted for initial droplet diameters ranging from 1.0 – 3.0 mm in size. The results show distinct combustion and extinction behavior. Increasing xenon concentration resulted in slower burning rate, larger extinction but longer total burn time. It is found that the limiting oxygen index (LOI) under xenon enriched conditions were significantly lower than that observed in the nitrogen or argon. The predicted combustion characteristics are in good agreement with recently conducted experiments onboard the ISS. The numerical results are further analyzed to determine the dominant factors that produce such lower LOI in xenon. The results of this computational study are also compared with published helium and carbon-dioxide enriched environment droplet combustion data in order to assess the diluents effect.

[C51.3] Cool flames in microgravity droplet combustion. A. Cuoci¹, A. Frassoldati¹, T. Faravelli¹, F.A. Williams¹. ¹Department of Chemistry, Materials, and Chemical Engineering, Politecnico di Milano (Italy), ²Department of Mechanical and Aerospike Engineering Department, University of San Diego California (USA).

Formation of cool flames around isolated droplets of n-heptane and n-decane burning in microgravity conditions is numerically studied in the present work. The adopted numerical model solves the unsteady transport equations of mass, momentum species and energy, both for the droplet and the gas phase, assuming a spherically symmetric domain. Detailed transport properties are accounted for both the phases (liquid and gas) and the droplet/gas interface is described assuming thermodynamic equilibrium. Radiative heat transfer is
accurately modeled in order to correctly capture the extinction phenomena leading to the formation of cool flames. A detailed kinetic scheme with ~300 species, accounting for the low-temperature mechanism, is adopted. The resulting model consists of a large, structured system of differential algebraic equations (DAE), with numerical complexity due both to the stiff nature of the kinetic mechanism and to the flame structure around the droplet.

The model was adopted to explain the anomalous combustion of hot-wire ignited n-heptane droplets, recently experimentally observed by Nayagam et al. [Combustion and Flame, 159 p. 3583–3588 (2012)]. In particular, after a first radiative extinction (i.e. the visible flame ceases to exist), relatively large, hot-wire ignited n-heptane droplets continue to strongly vaporize (according to the well-known squared-law) for an extended period, ending in a secondary extinction at a finite droplet diameter. The numerical results, in good agreement with the experimental measurements, showed that the second-stage vaporization is sustained by a low-temperature, soot-free, “cool-flame” at ~700 K, persisting for several seconds.

The numerical model was also applied to the autoignition (in air at 633 K) of n-decane droplets to analyze the experiments performed by Xu et al. [Int. J. Heat Mass Transfer, 46, p. 1155–1169 (2003)]. The relatively low ambient temperature prevents high-temperature ignition occurring, but the experimentally observed vaporization rates were found incompatible with pure evaporation regime. On the contrary, the numerical predictions showed that the observed vaporization rates can be easily explained by considering the presence of a cool flame around the droplet.

**[C51.4] Cool-Flame-Supported Second-Stage Burning of n-Decane Droplets in Microgravity. V. Nayagam, D.L. Dietrich, M.C. Hicks, and F.A. Williams. National Center for Space Exploration Research, NASA Glenn research Center, Cleveland, OH, USA; NASA Glenn Research Center, Cleveland, OH, USA; Department of Mechanical and Aerospace Engineering, University of California, San Diego, La Jolla, CA, USA.**

Recent droplet combustion experiments (FLEX) onboard the International Space Station (ISS) have revealed that large n-alkane droplets can continue to burn quasi-steadily following radiative extinction in a low-temperature regime, characterized by negative-temperature-coefficient (NTC) chemistry. In this study we report experimental observations of n-decane droplets of varying initial sizes between 1 and 5mm burning in oxygen/nitrogen and oxygen/helium/nitrogen environments at 1.0 and 0.5 atmospheric pressures. The oxygen concentration in these tests varied in the range of 14% to 30% by volume. As expected, large n-decane droplets exhibited quasi-steady low-temperature burning following radiative extinction and then pure evaporation when this second-stage combustion abruptly ends. As with the n-heptane results reported earlier (Nayagam et al. 2012), second-stage extinction is followed by vapor-cloud formation in most cases. However, unlike the n-heptane results, for some large droplets, the vapor cloud was found to form even before the completion of second-stage combustion. Results for droplet burning rates in both the hot-flame and cool-flame regimes as well as droplet extinction diameters at the end of each stage are presented. Time histories of radiant emission from the droplet captured using broadband radiometers are also presented. The n-decane results are compared with the n-heptane results, and the similarities and differences are discussed using simplified theoretical models of the phenomenon.

**[C51.5] Multistage Oscillatory “Cool Flame” Behavior For Isolated Alkane Droplet Combustion in High Pressure Microgravity Condition. T. I. Farouk and F. L. Dryer. Department of Mechanical Engineering, University of South Carolina, Columbia, SC, USA; Department of Mechanical and Aerospace Engineering, Princeton University, Princeton, NJ, USA.**

Recently conducted large diameter isolated n-heptane droplet experiments under microgravity conditions, showed unique Cool Flame burning behavior which is dictated by the heat loss mechanism and resulting in the transition to a quasi-steady low temperature second stage combustion. For atmospheric pressure the transition to the Cool Flame is followed by diffusion extinction and only a single hot – cool flame combustion phenomena is observed. With increasing pressure, multiple cycles of hot – cool flame transition is observed. In these multistage oscillatory mode the droplet starts as a classical hot flame and transitions to a cool flame and then transitions back to a hot flame repeating the cycle until the droplet extinguishes. Experimental examples of the multistage oscillatory mode of isolated n-heptane droplets under high pressure microgravity conditions are presented and analyzed numerically using a novel spherically symmetric droplet combustion code that includes full two-stage detailed chemical kinetics, multi-component transport, and spectral radiative interactions. The simulations indicate that at high pressure the low temperature chain branching reactions from the large fuel fragments; ketohydroperoxides propagates at a faster rate and enables the droplet to transition back to a hot ignition and hot flame. Numerical results are further analyzed in detail to identify key controlling experimental parameters and detailed kinetic properties that result in the noted observations. Predictions are found to be in good agreement with the experimental measurements.


Fuels derived from biomass have recently received extensive attention because of their potential as an alternative energy source to petroleum-based fuels. Butanol, in particular, is a potential competitor to ethanol for blending with conventional ground transportation fuels because of its higher cetane number, lower vapor pressure, and higher miscibility to diesel compared to ethanol. For these reasons it is important to understand the relevant combustion dynamics of this important organic molecule. This study reports experimental data that compares the combustion dynamics of butanol isomers, namely n-butanol, iso-butanol, 2-butanol, and t-butanol using the fundamental combustion configuration of near spherical symmetry as promoted by low gravity in the standard ambience. The initial droplet diameter was fixed at about 0.5 mm. The spherical droplet flame is the base case for liquid fuel combustion due to its one dimensional gas transport that is amenable to detailed numerical modeling. As such, the expectation is that the data reported will be useful to assess the performance of such models and the combustion chemistry incorporated in them.
A free-fall facility was used to create low gravity. The facility contained a sealed chamber with the deployed droplets anchored to a very small diameter (14 μm) SiC fiber in the internal gas environment (room temperature air in the present investigation), two high energy spark ignition electrodes placed on either side of the droplet, and high resolution digital imaging systems to record the droplet burning history from which quantitative data were obtained by computer imaging analyses software. The data reported include the evolution of the droplet (D) and flame (Df) diameters. The results showed that a soot shell structure was not observed during the droplet burning history. The droplet burning rates of the butanol derivatives examined were very close, with t-butanol showing the greatest differences. On the other hand, the relative position of the droplet to the flame showed noticeable differences for the butanol isomers that appeared to loosely correlate with molecular branching.

Supported by NNX08AI51G, National Aeronautics and Space Administration.

**Concurrent Session 52: Complex Fluids 4**

**Session Co-Chairs:** Fran Chiaramonte, NASA Headquarters, and Arjun Yodh, University of Pennsylvania

**Time:** Friday, 10:30 am – 12:00 pm

[CS2.1] Understanding the Link Between Bijel Morphology, Stability, and Processability. **Ali Mohraz.** Department of Chemical Engineering and Materials Science, University of California, Irvine. Bicontinuous interfacially jammed emulsion gels (bijels) are a new class of non-equilibrium soft materials with interpenetrating arrangement of two liquid domains separated by a monolayer of colloidal particles on a continuous 3D surface with zero mean curvature. This remarkable morphology is the result of arrested spinodal decomposition in a binary liquid mixture through interfacial colloidal jamming. The distinctive configuration of the constituent phases in bijels makes them uniquely suited for the template-based synthesis of composite materials with bicontinuous nanoarchitecture for electrochemical energy systems, tissue engineering, catalysis, and sensing. However, issues related to the stability of bijels against gravitational separation and their ability to withstand surface tension gradients during their processing has so far delayed the development of a robust materials synthesis platform based on these systems. This talk will focus on our current understanding of the physicochemical and morphological factors that govern the rheology and processability of bijels, and our future plans to investigate these relationships.

Supported by the Research Opportunities in Complex Fluids and Macromolecular Biophysics program at NASA Grant number NNX13AQ69G.

[CS2.2] Crystallization of Supercubes by Depletion. **A.D. Hollingsworth**, P.M. Chaikin, and S. Sacanna. 1 Dept. of Physics, 2 Dept. of Chemistry, New York University, New York, NY 10003, USA. We are studying the different crystal phases of “supercubes”, colloidal particles whose surface is defined by the equation $1 = \left(\frac{x}{a}\right)^m + \left(\frac{y}{a}\right)^m + \left(\frac{z}{a}\right)^m$, where $a$ is the semi-major axis length. When $m = 2$ this implicit function describes a sphere; when $m = \infty$, it describes a cube; and for $m > 2$ we have a cube-like structure with rounded edges and corners. We use different size depletants to compress the system and form crystals. In gravity, the structures are two dimensional, forming a hexagonal lattice for spheres, parallel rows for cubes and a square lattice for supercubes in the limit where the size of the depletant allows it to enter the crystal interstices. We will also discuss our planned microgravity mission which will allow the study of three dimensional crystals.

Supported by NASA grant award NNX08AK04G.

[CS2.3] Electric Field-Driven Phase Transitions in Polarized Colloids. **B. Khusid**, H. Löwen, E.S. Nelson, C.C. Sheehan, M.M. Telo da Gama, and Y. Anand. 1 New York Institute of Technology, Newark, NJ, USA, 2 Heinrich-Heine-Universität Düsseldorf, Düsseldorf, Germany, 3 NASA Glenn Research Center, Cleveland, OH, USA, 4 ZIN Technologies Inc., Cleveland, OH, USA, 5 Universidade de Lisboa, Lisboa, Portugal, 6 Memorial University of Newfoundland, St John’s, NL, Canada.

We will present our approach to the development and conducting experiments aboard the International Space Station to elucidate the fundamental microscopic mechanisms of phase transitions in colloids subjected to spatially and time varying electric fields. A requirement for precise matching of densities between particles and a host fluid in order to avoid undesirable gravity effects severely limits the possibilities for varying a particle-fluid polarization contrast in terrestrial experiments. We hypothesize that experiments in microgravity over a sufficiently long time should reveal the salient features of field-driven phenomena in polarized colloids as the particle-fluid polarization contrast that governs interactions of particles with an applied non-uniform field and interparticle dipole-dipole forces will be varied in a wide range by using non-buoyancy-matched particles and fluids. The emphasis will be on the field-driven evolution of the mesoscale phase transitions, electro-hydrodynamic instabilities and nucleation and growth of crystalline structures. The phenomena selected are logical candidates to take advantage of microgravity because terrestrial observations have failed to provide a comprehensive physical understanding of the underlying physics.

Supported by NASA’s Physical Science Research Program, NNX13AQ53G.

[CS2.4] Colloidal Discotic Liquid Crystals. **Zhengdong Cheng.** Artie McFerrin Department of Chemical Engineering, TAMU, College Station, Texas 77843-3122.

Despite their natural abundance and wide industrial applications, such as red blood cells and clay, disks are the least studied colloidal systems compared to geometries like spheres and rods. We established methods to fabricate and control the size, aspect ratio, and polydispersity of disks and systematically investigate their effects on discotic liquid crystal phase transitions. This talk will focus on surface controlled shape design of discotic microparticles using phase change emulsions and the observation of the discotic liquid crystal phases using nanoplates with identical thickness. Comprehensive understanding of the colloidal discotics in terms of complex fluids behaviors and liquid crystal transitions will help establish theory for model atomic liquid crystals and develop industrial applications.

Supported by NSF DMR-1006870 and NASA-NNX13AQ60G.
INVESTIGATOR AND STUDENT POSTER SESSION
TUESDAY, NOVEMBER 5, 2013 (6:00 PM – 8:00 PM)

Investigator Posters:
6:00-7:30 pm – Even numbered posters
7:30-9:00 pm – Odd numbered posters

[IP.1] Fatty Acid Content and Microviscosity in Pea Seedlings Plasmalemma Under Clinorotation. O.M. Nedukha¹, E.L. Kordyum¹, V.P. Grakhot¹, T.V. Vorobyova¹, and I.V. Zhupanov¹. ¹Institute of Botany of Nat. Acad. Sci. of Ukraine. Kiev, Ukraine 01601, Kyiv, Tereschenkivska str., E-mail: o.nedukha@hotmail.com; ²Botanical Garden of Nat. Acad. Sci. of Ukraine. Kiev, Ukraine, 01014, Kyiv, Timiryazevska str., 1. The functions biological membranes and role of lipid components of plant cell plasmalemma at altered gravity are still unclear. The comparative study of fatty acids content, an unsaturation index and microviscosity of plasmalemma from pea plant root and epicotyl in the stationary control, and under horizontal clinorotation (2 rev/min) was carried out. Roots are characterized with positive gravitropic reaction, and epicotyls - with negative ones, accordingly. The fraction of plasmalemma was obtained by the method of two-phase system. It contained near 97% plasmalemma vesicles. We observed plasmalemma vesicles by transmission electron microscopy. Fatty acids composition and content in the plasmalemma fraction are analyzed with liquid thin chromatography; its microviscosity was detected with electron spin resonance. It was established the differences in physical-chemical properties of the plasmalemma fraction obtained from roots and epicotyls in the stationary conditions and under clinorotation. In addition, there are the differences of those parameters in the plasmalemma fraction formed from roots and epicotyls under clinorotation. The plasmalemma from roots was shown to be more sensitive to action of clinorotation in comparison with that from epicotyls.

[IP.2] Ankle Plantar-flexion is Essential for Mobilization of Soleus during Cycling and Weight-lifting Exercise in Human. H. Okabe¹, Tak. Ohira², F. Kawano³, Y. Oke³, R. Fujita³, Tomo. Ohira³, K. Ohira³, N. Nakai³, H. Naito³, K. Goto³, and Y. Ohira³. ¹Grad. Sch. Health Well-being, Kansai Univ., Osaka, ²Front. Biosci. & Med., Osaka Univ., Osaka, and ³Grad. Sch. Health Sci., Toyohashi SOZO Univ., Aichi, ¹Grad. Sch. Engineering, Tottori Univ., Tottori, ²Grad. Sch. Health Sp. Sci., Juntendo Univ., Chiba, and ³Res. Ctr. Adipocyte Muscle Sci., Doshisha Univ., Kyoto, Japan. Exercises in space are not always effective for prevention of atrophy in soleus, which is most susceptible to gravitational unloading. Therefore, this study was performed to investigate the optimum exercise prescription for prevention of the gravitational unloading-related atrophy in human soleus. Electromyogram (EMG) activities in soleus were recorded in 7 healthy male subjects during 1) cycling at 70, 130, and/or 170W, by pedaling using arch or front sole, and 2) weight lifting (isometric and/or squat push-up) by whole sole or front sole. Greater EMG levels were observed, when the load was increased and the subjects pedaled by using front sole. EMGs were also greater, when the weight lifting was performed by using front sole than whole sole. It was clearly suggested that plantar-flexion of ankle joints is essential for stimulation of soleus mobilization.

[IP.3] Role(s) of Neural Factor(s) in the Unloading-related Atrophy of Ankle Extensors in Rats. Tak. Ohira¹, F. Kawano⁰, Tomo. Ohira¹, L. Ohira¹, H. Okabe¹, K. Goto¹, and Y. Ohira¹. ¹Grad. Sch. ²Front. Biosci. & Med., Osaka Univ., Osaka, ³Grad. Sch. Health Sci., Toyohashi SOZO Univ., Aichi, ¹Fac. Health Well-being, Kansai Univ., Osaka, ²Fac. Let., Kokushikan Univ., Tokyo, and ³Res. Ctr. Adipocyte Muscle Sci., Doshisha Univ., Kyoto, Japan. Responses of the mass in ankle extensors, in which the in vivo lengths are shortened by ankle plantar-flexion, to denervation were studied in male adult Wistar rats (n=12). Six rats served as the cage control. The remaining 6 rats were hindlimb-suspended keeping the left limb intact. But denervation was performed in the right limb at the gluteal region under anesthesia with i.p. injection of sodium pentobarbital (5 mg/100 g body weight). Food and water were supplied ad libitum during the 10-day experimental period. Significant reduction of body weight (~14%) was noted in response to hindlimb suspension with free or fixed ankle joints. Slow-twitch soleus and fast-twitch plantaris, and medial and lateral gastrocnemius muscles were sampled from each rat under anesthesia with i.p. injection of sodium pentobarbital. Atrophy in soleus (~42%) caused by hindlimb suspension with intact innervation was greater than plantaris (~31%) and medial and lateral portions of gastrocnemius (~32%), suggesting that slow muscle is more susceptible than fast muscles even though these muscles play ankle plantar-flexion similarly. Atrophies in the fast-twitch muscles were further promoted significantly by denervation in addition to suspension, although the mass of soleus was unaffected. It was clearly indicated that soleus muscle is more susceptible to unloading than other fast-twitch agonists. It was further suggested that cumulative effects of unloading and denervation are induced in the fast-twitch muscles, but not in slow-twitch soleus.

[IP.4] Gravitational Potentials and Dynamics of Galaxies Against The Cosmological Background. M. Eingorn. CREST & NASA Research Centers, North Carolina Central University, Durham, NC, USA. The Universe is considered deep inside the cell of uniformity, where it is filled with inhomogeneously distributed galaxies perturbing the cosmological background (described, e.g., by standard models with conformally flat, spherical or hyperbolic spaces). In the framework of the recently developed mechanical approach to cosmological problems inside the cell of uniformity, it is shown that only in the last case there exists an explicit expression for the gravitational potential of an arbitrary number of randomly distributed inhomogeneities, finite at any point including spatial infinity. Bearing this result in mind, dynamics of Milky Way and Andromeda as well as surrounding dwarf galaxies forming the Hubble flow is investigated and illustrated in detail, taking into account both the gravitational attraction between them and the cosmological expansion of the Universe. It is demonstrated that there are always characteristic dimensions at which these two opponents become comparable. For our group of galaxies it happens theoretically at approximately 1 Mpc in agreement with the observations. Besides, the future collision between Milky Way and Andromeda is considered in the cosmological context in presence and absence of dynamical friction. The corresponding critical values of parameters of the problem are found. Supported by NSF CREST award HRD-0833184 and NASA grant NNX09AV07A.
[IP.5] Contractile Mode and Work Volume Influences on Lactate and Testosterone Values from Flywheel-based Exercise. J.F. Caruso1, M.A. Urquhart2, R.M. Giebel1, A.G. Barbosa1, L.A. Learmonth1, M.L. Mason1, K.D. Unruh1, J.A. Borgsmiller1, and W.T. Potter2. 1Exercise and Sports Sciences Program, 2Department of Chemistry and Biochemistry, The University of Tulsa, Tulsa, OK, USA.

For extended stays in microgravity, in-flight exercise abates muscle mass and strength losses. In-flight resistive exercise is based on eugravity strength training principles yet performed on novel flywheel-based hardware. In-flight workout prescriptions may be better served from examination of changes to lactate and testosterone, as the degree of their post-workout increase indicates the merits of the mechanical loading stimulus provided by exercise. To make such protocols pertinent to microgravity they should examine unique features of flywheel-based hardware, such as the option to exert eccentric torque. Our study compares blood lactate concentration ([BLA]) and testosterone changes from leg press workouts that differ by contractile mode and work volume, on a flywheel-based exercise hardware (YoYo Technologies; Stockholm, Sweden). Participants (17 men, 18 women) performed three workouts; two entailed two sets of concentric-eccentric (CE2) or concentric-only (CO2) actions. A third involved four sets of concentric-only actions (CO4). CE2 and CO4 should entail similar volumes of work, and each should be twice that of CO2. Total work (TW) was quantified per workout. Testosterone was measured before and after workouts. [BLA] were assessed pre- and at 0-, 5-, 10-, 15- and 20-minutes post-exercise. TW data were analyzed with a one-way ANOVA with three (CE2, CO2, CO4) levels. [BLA] were evaluated with a 3x6 ANOVA with repeated measures for workout and time. Testosterone data were compared with a 2x2x3 ANOVA with repeated measures for workout and time. With Scheffe’s post-hoc and α = 0.05, our results showed TW had an inter-workout (CE2, CO4 > CO2) difference. [BLA] included an interaction as CO4 workouts evoked higher post-exercise values per time point examined. Testosterone data had gender (men > women) and time (post > pre) main effects. Despite greater post-exercise [BLA] values, CO4 did not confer greater endogenous testosterone secretion than CE2. Results suggest flywheel-based resistive exercise protocols should see half their work done eccentrically, as CE2 elicited comparable testosterone increases without the higher [BLA] incurred from a similar volume of work comprised solely of concentric (CO4) actions.

Support provided by a University of Tulsa Faculty Research Grant.


Genetically encoded filamentous actin (F-actin) reporters designed based on fluorescent protein fusions to F-actin binding domains of actin regulatory proteins have emerged as powerful tools to decipher the role of the actin cytoskeleton in plant growth and development. However, these probes could interfere with the function of endogenous actin binding proteins and in turn impact actin organization and plant growth. We therefore surveyed F-actin organization and compared organ growth in Arabidopsis thaliana lines expressing a variety of F-actin markers. Here we show that the variant of fluorescent protein, type of actin binding domain, and the promoter that drives reporter expression can influence organ growth and quality of F-actin labeling. For example, red emitting probes such as DsRed and mOrange induced more aberrant F-actin structures compared to green emitting fluorophores such as GFP and YFP. Moreover, plants expressing reporters based on Talin and Lifeact decorated more prominent F-actin bundles in above ground organs compared to ABD2-based reporters. Finally, the use of the ubiquitin10 (UBQ10) promoter to drive expression of the GFP-ABD2-GFP probe minimized silencing and eliminated the growth defects induced by stable expression of the 35S-driven version. Taken together, this study shows that care must be taken in the interpretation of data derived from stable expression of certain F-actin reporters and that using alternative promoters such as UBQ10 can overcome some of the pitfalls that accompany the use of in vivo F-actin probes in plants.

Supported by NASA grants NNX10AF43G and NNX12AM94G.


Microgravity research experiments on either suborbital Reusable Launch Vehicles (sRLVs) or the International Space Station (ISS) require isolation of the research payload from the milli-g flight environment of the host vehicle. To achieve payload isolation suitable for microgravity research, the Vibration Isolation Platform (VIP) from Controlled Dynamics Inc. provides a payload mounting interface which includes both active stabilization and 6-DOF non-contact isolation. The technology was originally demonstrated with a fluid physics experiment inside a middeck locker on STS-73 in October 1995 and it is currently undergoing demonstration flights on suborbital Reusable Launch Vehicles (sRLVs).

The VIP provides a microgravity payload interface compatible with any current or emerging sRLV as well as a variety of sounding rockets. Completely autonomous, the VIP automatically releases, stabilizes, and recaptures the free-floating platform and attached research payload during the appropriate phases of flight. A “µg OK” discrete signal is provided to the payload when the acceleration environment is acceptable for conducting microgravity research. An optional turntable is available for axial spin cancellation on sounding rockets or crewed sRLVs that may maneuver during free-fall.

For use on ISS, the VIP payload mount is packaged into a middeck locker. This provides component-level isolation of the research payload on ISS, which allows for isolation from other payloads on the same rack as well as high-bandwidth active stabilization to attenuate any payload-induced disturbances. These capabilities are an improvement over the existing active rack isolation system on ISS, and they allow the VIP locker to achieve a microgravity research environment in any EXPRESS rack on the ISS rather than just those racks equipped with the active rack isolation system. Using the measured flight environment in the Destiny lab on ISS, the VIP is shown to attenuate the 4.3mg-rms ambient environment down to <8µg-rms on the isolated platform. Performance predictions based upon measured data from UP Aerospace SpaceLoft® flights will be presented.

The VIP development is funded under NASA’s Space Technology Mission Directorate, contract # NND12AD71C.
[IP.8] Dynamic Analysis of the Center of Gravity Using Mouse and Study of Motion Efficiency. Tomomi Kawasaki1, Souji Aou2, Yasuhiro Kumei3, Katsuya Hasegawa3, Japan Aerospace Exploration Agency, 2Graduate School, Kyushu Institute of Technology, 3Graduate School, Tokyo Medical and Dental University.

An animal is adapted for ecology in process of evolution, and is carrying out various forms. Therefore, although a living thing performs movement suitable for each form, it is thought that the method has taken the optimal and efficient method in each form. At rest, the center of gravity, which is held by the feet of four-legged animal is consistent with the center of gravity of the body. But when the animal moving, both the center of gravity will not match because animal break the balance held in order to perform the movement. In this study, as a method to measure the efficiency of movement way of animals, we analyzing the center of gravity which is held by the feet of four-legged animal and Dynamic movement of the center of gravity by walking, and consider the motion efficiency by comparing the movement of the center of gravity which is held by the feet of four-legged and the moving direction.

Because mouse is only tens of grams body weight and their kick power is also weak, we develop the center of gravity meter suitable for a mouse which can measure dynamic changes, and succeed in visualization of center of gravity movement of the mouse by dynamic measurement. Since the direction and movement speed is also important, we take the picture of the visible image at the same time as the center of gravity measurement. and measure the direction and speed of movement of the mouse from the analysis of the video image. By analyzing the synchronous change of the center of gravity and speed of movement, it made possible to observe the change in center of gravity in a motion.


A specific challenge in conducting space experiments is the expectation to utilize existing spaceflight hardware to answer complex biological problems that are unique to microgravity. Therefore, the Science Verification Test (SVT) and the Payload Verification Test (PVT) are essential operations to ensure successful spaceflight studies. We have completed both the SVT and the PVT for our upcoming APEX 02-1 space experiments where we proposed to use the Advanced Biological Research System (ABRS) on the International Space Station (ISS) to uncover molecular mechanisms by which microgravity modulates root development and cell wall architecture. Here, we report on our SVT and PVT results focusing primarily on lessons learned as we prepared Arabidopsis seedlings for growth on the ABRS and subsequent post flight processing of seedlings fixed on Kennedy Fixation Tubes (KFTs). One problem encountered during SVT was the premature germination of seeds prior to experiment activation. This problem was mitigated by exposing seeds (Columbia ecotype) planted on square Petri dishes to 10 minutes of red light and maintaining plates in complete darkness at 4°C prior to installation on ABRS. This simple procedure kept seeds in a dormant state and germination only occurred when seeds were exposed to white light on ABRS. In regard to processing seedlings fixed in KFTs, both RNA quality and yield for the planned RNA-Seq studies was very good. RNA integrity numbers (RINs) ranged from 8.0 to 8.7. However, preservation of seedlings for microscopy gave varied results. We found that seedlings fixed with glutaraldehyde in KFTs and embedded in LR White resin, preserved antigenicity of seedling roots to non-fucosylated xyloglucan as revealed by confocal microscopy. Ultra-structure was adequately preserved under the transmission electron microscope (TEM).

Because the decreased potency of glutaraldehyde was due to its extended contact with oxygen while stored on KFTs. During the PVT, we made minor modifications to address fixation problems. We expect that the lessons learned from SVT and PVT will lead to the successful implementation of APEX 02-1.

Supported by NASA grant NNX12AM94G.

[IP.10] Dust Acoustic Instability in a Strongly Coupled Dusty Plasma. M. Rosenberg1, G. J. Kalman2, P. Hartmann3, and J. Goree4. 1University of California, San Diego, 2Boston College, 3Institute for Solid State Physics, Wigner Research Centre for Physics, Hungarian Academy of Sciences, 4The University of Iowa.

Microgravity conditions enable experiments with three-dimensional dusty plasmas that occupy a three-dimensional volume, which is not practical under 1 g conditions due to sedimentation. Dusty plasmas are plasmas containing fine charged dust grains (solid particulates) that occur in a wide variety of cosmic and terrestrial environments. Microgravity experiments with dusty plasma are planned for the PK-4 and PlasmaLab instruments, which are in development for the International Space Station. Dust is also a common component of space and astrophysical plasmas, occurring for example in planetary rings, comet tails, the Earth’s mesosphere, and the interstellar medium. Dusty plasmas are important in microelectronics manufacturing and in lunar and Martian habitats, where dust poses a contamination problem.

Because the dust grains can be multiply charged and are much more massive than the ions, the presence of dust can lead to novel wave phenomena. Dust can cause changes in both the classical and quantum electrodynamics of plasma, since dust grains can possess a much larger electric field than can the ions. The density and size of dust grains also affect the plasma density and temperature. In addition, dust grains can interact with the plasma via Coulomb forces, which can lead to new phenomena such as the dust acoustic wave, which is a compressional wave that can be excited by a flow of ions that is driven by an electric field. Moreover, the large dust charge can result in strong Coulomb coupling between the dust grains, where the electrostatic energy between neighboring grains is larger than their thermal (kinetic) energy. When the coupling between dust grains is strong, but not large enough for crystallization, the dust is in the strongly coupled liquid phase, as is expected for PK-4. This poster theoretically investigates the dust acoustic instability, which is driven by sub-thermal ion flow, in a dusty plasma in the strongly coupled liquid phase. Microgravity conditions enable the preparation of dust clouds under these sub-thermal ion flow conditions by avoiding the need for strong electric fields to levitate the dust grains.

[IP.11] ESA’s Atmosphere-Space Interactions Monitor (ASIM) for the ISS. A. Orr. ESA/ESTEC, Keplerlaan 1, PO Box 299, NL-2200AG Noordwijk, The Netherlands.

The Atmosphere-Space Interaction Monitor (ASIM) is an Earth observation facility of the European Space Agency (ESA) planned for the external platform on the Columbus module of the International Space Station (ISS). It will mainly study the giant electrical discharges (lightning) in the high-altitude atmosphere above thunderstorms.
The discharges are seen as optical-, X- and Gamma-ray flashes in the stratosphere and mesosphere. The optical emissions are called “red sprites”, “blue jets”, and “elves” or “Transient Luminous Events” (TLEs). The X- and Gamma-ray emissions are referred to as “Terrestrial Gamma-Ray flashes” (TGFs). The ASIM Science payload is composed of nadir-looking detectors. The optical waveband is observed with the help of cameras and photometers. The X to Gamma-ray waveband is covered using a soft gamma-ray imager with extended spectroscopic capabilities up to 20 MeV. ASIM is part of ESA’s “European Programme for Life and Physical Sciences” (ELIPS). This poster describes the science goals of ASIM, the payload and current status of the Project.

On behalf of: ESA’s Science, Project and Operations team, the ASIM Science Team and Space Industry; DTU-Space (DK), University of Valencia (ES), University of Bergen (NO), CEA DASE/LDG (FR), Terma A/S (DK), CGS S.p.A. (IT), INTA (ES), PAS/SRC (PL).


PK-4 ("Plasma Kristall-4") is an experiment of the European Space Agency (ESA) for investigating Complex Plasmas in micro-gravity. PK-4 follows a long line of prolonged complex plasma experiments in space. PK-4 is currently in Phase C with ESA. PK-4 is foreseen to be installed on the Columbus Module of the International Space Station (ISS). The experiment apparatus of PK-4, composed of a plasma chamber and diagnostic instruments and sealed within a container, includes a “tele-science” unit to provide an interface to the ISS crew. A complex plasma is a low-temperature gaseous mixture composed of ionized gas, neutral gas and micron-sized particles. Complex plasmas are strongly coupled plasmas in which the interaction energy between the plasma particles is larger than the kinetic energy of the particles. Due to the strong influence of gravity on the micro-particles, most experiments on complex plasmas are strongly distorted or even impossible on Earth and thus require microgravity conditions. PK-4 is a laboratory which enables a large variety of complex plasmas experiments. It is also able to react to new developments in the field in a flexible manner. The main interest lies in the investigation of the liquid phase and flow phenomena of complex plasmas for which PK-4 is especially suited thanks to a DC-discharge plasma and due to its geometry (an elongated glass tube with a large observational access). This poster describes the science goals of PK-4, the payload and current status of the project.

On behalf of: ESA’s Science, Project and Operations team, PK-4 Science Team and Space Industry; Max Planck Institute for Extraterrestrial Physics (DE), JIHT RAS (RU), University of Giessen (DE), University of Tromsø (NO), University of Iowa (US), Auburn University (US), Royal Institute of Technology KTH (SE), GREMI-Polytech'Orléans (FR), University of Napoli INFM (IT), Università degli Studi del Morlise (IT), Eindhoven University of Technology (NL), Kayser-Threde GmbH (DE), DTM Technologies (IT).

[IP.13] ESA’s SOLAR Observatory on the ISS. A. Orr. ESA/ESTEC, Keplerlaan 1, PO Box 299, NL- 2200AG Noordwijk, The Netherlands.

The European Space Agency’s SOLAR payload is a solar observatory on-board the International Space Station (ISS), located on the zenith external platform of ESA’s Columbus module. It was launched with Columbus in February 2008 and has been operating since then. SOLAR is a payload that accommodates two solar science instruments (SOLACES, SOLSPEC) onto one Columbus External Payload Adapter (CEPA). In order to support the observation of the sun the SOLAR Instruments need to be pointed towards the sun. This function is achieved by the means of a dedicated pointing device (the Coarse Pointing Device (CPD). In order to avoid atmospheric absorption one needs to measure the solar electro-magnetic radiation from outside the Earth’s atmosphere. The science goal of SOLAR is to obtain absolute measurements of the solar spectrum. Both SOLAR instruments include on-board calibration which makes it possible to derive absolute irradiances. The SOLSPEC instrument measures the absolute solar spectral irradiance from 180 nm to 3000 nm and studies the solar variability over both short and long time scales. SOLACES measures the EUV/UV absolute solar spectral irradiance between 15 nm and 220 nm.

On behalf of: ESA’s Science, Project and Operations team and the SOLAR Science Team.

[IP.14] ESA’s Planet Precursors Experiment for the ISS: “ICAPS.” A. Orr. ESA/ESTEC, Keplerlaan 1, PO Box 299, NL- 2200AG Noordwijk, The Netherlands.

The ICAPS experiment of the European Space Agency (ESA) addresses planetary science. Its aim is to understand the formation of planetesimals, or planet precursors, by studying the mutual interactions of micron-size dust particles and their agglomeration in conditions representative of pre-planetary conditions. Its goal is also to study the light scattering behaviour of proto-planetary dust aggregates - as they form. Although the basic concept of the experiment is simple, its scientific potential is far-reaching and its technical development is extremely challenging. The start of project phase C/D is currently being prepared. ICAPS is intended to fly in the Columbus module of the International Space Station (ISS). The ICAPS scientific experiment will consist of: a vacuum chamber surrounded by an injection unit for dust particles, several diagnostic tools, particle manipulation tools and a cleaning system to ensure transparent chamber windows and to avoid experiment contamination between different types of dust particles. The diagnostic tools will include photodiodes, polarimeters, overview cameras, microscopes. The tools for particle manipulation consist of an optical manipulation system and a device to confine the particles within the centre of the chamber. This device is currently foreseen to be based on the thermophoretic principle. The most challenging aspects of the ICAPS experiment are, at the moment, the realization of the “thermophoretic” dust confining device, the cleaning of the experiment chamber and windows and the accommodation of all the diagnostic instruments and light sources around a small-sized chamber. This talk describes the science goals of ICAPS, the payload and current status of the project.

On behalf of: ESA’s Science, Project and Operations team, the ICAPS Science Team; CNRS-LATMOS, UPMC (FR), LPCE/CNRS (FR), Technical University of Braunschweig (DE), Universität Duisburg-Essen (DE), Université Laval (CA), Université Libre de Bruxelles MRC (BE), Institute of Astrophysics of Andalucia CSIC (ES).
Antioxidant supplement for prevention of capillary regression and inhibition of thrombospondin-1 in unloading-induced atrophied muscle.  H. Fujino, M. Kanazashi, H. Kondo, S. Murakami, F. Nagatomo, A. Ishihara.  Kobe University, Kobe, Japan, Food Science and Nutrition, Nagoya Women’s University, Nagoya, Japan, Physical Therapy, Himeji Dokkyo University, Himeji, Japan, and Cell Biology and Life Science, Kyoto University, Kyoto, Japan.

Oxidative stress is proposed as the initial pathologic step of skeletal muscle and endothelial injuries during unloading. The purpose of the present study was to investigate the protective effects of antioxidant on capillary regression in the soleus muscle during hindlimb unloading (HU) and to elucidate the regulations of pro- and antiangiogenic factors. Twenty-four male Wistar rats were assigned randomly either to a control, control treated with astaxanthin (AST), HU, or HU treated with AST group. Three-dimensional visualization of the capillary network in the soleus muscle was performed using a confocal laser microscopy. HU for 7 days resulted in a decrease in muscle mass and capillary-to-fiber ratio in the atrophied soleus muscle. In addition, the capillary network in the soleus muscle appeared to be less complex in the HU than in the other groups, i.e., smaller diameter, less tortuous capillaries and fewer anastomoses. These observations are reflected in the lower mean capillary volume and luminal diameter in the HU compared to all other groups. Furthermore, the overexpression of reactive oxygen species and SOD-1, a decrease in the level of pro-angiogenic factors, and an increase in the level of thrombospondin-1 (TSP-1), as an anti-angiogenic factor, were observed in the atrophied muscle. Administration of AST attenuated the changes in SOD-1, VEGF, TSP-1, and other angiogenic factors, and prevented the capillary regression in the atrophied muscle. Interestingly, the mean capillary volume in the HU treated with AST group was similar to that in both control groups. Furthermore, the VEGF-to-TSP-1 ratio was higher in the AST treated groups than in the control and HU groups. These results suggest that AST may be an effective treatment to counter a chronic periods of decreased loading and activity levels in the capillary network in skeletal muscles and associated with angiogenic factors.

Supported by Grants-in-Aid for Science Research from the Japanese Ministry of Education, Culture, Sports, Science and Technology.
pharmacy can be carried on long-duration missions, the development of resistance to multiple antibiotics is a concern for mission planning. In support of the BRIC-18 experiment scheduled for launch to the ISS in December 2013, we have initiated ground-based experiments to address the question whether simulated microgravity affects the frequency of resistance to the model antibiotics rifampicin (RFM) and trimethoprim (TMP). In these experiments, the non-pathogenic bacterium Bacillus subtilis strain 168 was cultivated for 6 days at ISS ambient temperature in 10-ml High Aspect Ratio Vessels (HARVs) on two 4-place clinostats (Synthecon) oriented either vertically (V) or horizontally (H). Cells were harvested, enumerated and plated onto medium containing RFM (5 micrograms/ml). The frequency of mutation to RFM resistance was calculated, and RFM-resistant mutants were plated onto medium containing the second antibiotic, TMP (5 micrograms/ml) to determine the frequency of mutation to double (RFM+TMP) resistance. After 6 days of cultivation: (i) V-cultures showed higher cell densities than H-cultures and (ii) V-cultures showed higher frequencies of mutation to RFM resistance than H-cultures. We are currently determining the frequency of double RFM+TMP-resistant mutants. Complete results will be presented.

Supported by a grant from NASA (NNX12AN70G) to W.L.N. and P.F.-C. and a NASA-Florida Space Grant Consortium Summer Aeronautics Internship Program internship to R.N.

[IP.19] Profiling Gene Expression in Brassica Roots at High Spatial and Temporal Resolution. Myoung Ryoul Park, Yi-Hong Wang, and Karl H. Hasenstein. Department of Biology, University of Louisiana, Lafayette, LA 70504, USA.

We designed experiments to examine the mRNA profile in primary roots of Brassica rapa seedlings. Based on previously developed solid phase gene extraction (SPGE), we assessed changes in the expression of GLK (Glucokinase) during the first day post-germination using qPCR. The mRNA load of the extraction probe was about 2.1 ng per needle directly from tissue and was reduced by 80% after washing. However, the expression of ACT7 was not affected. When stored at 4°C for 2 week, SPGE needles can be reused without significant changes. The number of copies of the investigated genes changed spatially along the length of primary roots. In comparison with ACT7, UBQ was similarly expressed in the meristematic zone (MZ) and the expression of Tub increased 4-fold in the elongation zone (EZ). The expression level of all genes differed significantly at each sample position. The temporal expression of UBQ was highest in the MZ 9 h after germination and higher than at any other sample position. Expressions of GLK in EZ and root shoot junction (RS) increased gradually over time. The results indicate that SPGE extraction is the result of oligo-dT and oligo-DA hybridization and illustrate that SPGE can be used for gene expression profiling at high spatial and temporal resolution. ACT7, Tub1, UBQ, and GLK are expressed differently along the root length. Thus, gene expression studies that are based on the entire root miss differences in gene expression that SPGE is able to resolve.

Supported by NASA grant NNX10AP91G.

[IP.20] Drosophila Habitat with Flight Heritage Developed to Support Research On-board ISS. Matthew Lera 1, 2, William Wade 1, Shilpa Ravi Shankar 2, Kevin Martin 1, Sharmila Bhattacharya 1. 1NASA Ames Research Center, 2Lockheed Martin.

The Fruit Fly Lab is a hardware suite being designed to support Drosophila research on the International Space Station. A validation mission will launch and return on SpaceX-5 in late 2014, followed by the first Principal Investigator-lead science flight that will launch and return on SpaceX-7 in 2015. The cassette (containers) that will house the Drosophila cultures were successfully used to conduct an immunity study on Space Shuttle in 2006. Each cassette has a removable food tray that can be replaced to sustain the growth of the culture, or can be transferred to another cassette, along with embryos and burrowed larvae, enabling multi-generational studies. The cassette can be frozen in the Minus Eighty Laboratory Freezer for ISS (MELFI) to preserve samples until post-flight analysis, expanding the applications of the hardware and overcoming the loss of rapid sample turnover that resulted when Shuttle was retired. A food tray change-out platform is used to maintain containment during food maintenance operations, and allows ISS crew to perform operations quickly and safely without the need for a glove box. The food tray change-out platform can be preloaded with food trays containing microbial challenge organisms, which allows for easy administration of treatments on-orbit to support immune response studies, a capability that will be demonstrated on the initial validation flight. The cassettes slide into standard Type-I containers (ESA), and are compatible with the BioRack centrifuge (Astrium/NanoRacks) currently on-board ISS. Utilization of this centrifuge allows for on-orbit 1g controls for microgravity experiments, as well as variable g-levels for lunar or Mars environment studies. The standard form factor also allows for implementation of modular upgrades. An observation system, circadian rhythm lighting system, and fixation capability are upgrades being planned for implementation in the near future. This hardware suite, with its flight-proven design and ability to utilize on-board facility capabilities that already exist, offers the space biology research community a platform to address several key areas of the decadal survey, supporting the utilization of ISS for science discovery.

[This work is supported by NASA’s Space Life and Physical Sciences Research and Applications and the ISS NASA Research Office.]

[IP.21] Atomistic simulation of ceria nanoparticles to counter radiation induced damages. Amit Kumar 1, 2, Ram Devanathan 3, and Sudipta Seal 1, 2, 4. 1Advanced Materials Processing and Analysis Center, 2Materials Science and Engineering, University of Central Florida, Orlando, FL-32816, 3Fundamental and Computational Sciences Directorate, Pacific Northwest National Laboratory, Richland, WA-99352, and 4NanoScience Technology Centre, University of Central Florida, Orlando, FL-32816.

Radiation is one of the major hindering blocks in the long term manned space exploration. Radiation induced damage affects the performance of materials system as well as the living system. Several metal oxide systems with fluorite structure have been shown to counter radiation induced damage. Among the fluorite structure, nanostructured cerium oxide (CeO2) is also shown to mimic behavior of naturally occurring antioxidants in the body. Thus cerium oxide has recently gained tremendous attention among researcher for investigation towards its interaction with radiation. The benign property of cerium oxide nanoparticles stems from the dual valence stat of cerium (Ce) in the +4 and +3 states. The current study aims at the understanding the interaction of radiation induced damage in cerium oxide nanoparticles of different valence state with...
the aid Monte Carlo assisted atomistic simulation. Classical molecular dynamics is used to simulate the cerium oxide nanoparticles with different valence states using amorphisation and recrystallization strategy established in literature. The irradiation of ceria nanoparticle is studied using displacement cascade model, where a primary knock on atom is provided energy and the disturbance in the lattice is studied. The displacement cascades are modeled for high energy ionizing radiation of 2, 4, 6 MeV He\textsuperscript{+} ions in three different ceria nanoparticles with 5, 10, 15, 20% Ce\textsuperscript{3+} of size \textasciitilde10 nm. Monte-Carlo assisted molecular dynamics simulation serves as an effective tool to understand the radiation event in cerium oxide nanoparticles. It was observed that the entire simulated cerium oxide nanoparticles showed increasing defect density with ionizing energy radiation. However for the same energy of ionizing radiation, cerium oxide nanoparticles with 20% Ce\textsuperscript{3+} showed a much higher defect density As compared to 5, 10, 15% valence state cerium oxide nanoparticle. Studies underway are focused on understanding the role of valence state of cerium and size of cerium oxide nanoparticles on encountering the radiation induced damages. The research was performed using EMSL, a national scientific user facility sponsored by the Department of Energy’s Office of Biological and Environmental Research and located at Pacific Northwest National Laboratory. The research and travel were supported by NSF (Grant # 0708172).

**[PI.22] Adventures of the Agronauts: Mars Mission – An Online Resource for Teaching Middle Grade Science.** Amber Vogel\textsuperscript{1}, Jobi Cook\textsuperscript{2}, and Christopher S. Brown\textsuperscript{2,3}. 1Morehead Planetarium and Science Center; 2North Carolina Space Grant; 3University of North Carolina General Administration.

Creating effective curriculum resources that keep pace with evolving scientific knowledge and changing classroom requirements is a challenge placed before formal and informal science educators. **Adventures of the Agronauts: Mars Mission** is an online tool that engages middle school students in a comparative approach to learn about factors that allow or prevent plant life on Earth and other terrestrial planets. **Adventures of the Agronauts: Mars Mission** is based on a character and concept originated by NC Space Grant and the Kenan Fellows program that draws upon new findings from NASA missions. NC Space Grant collaborated with Morehead Planetarium and Science Center to create this interactive learning experience for students and supporting materials for their teachers, including lesson plans, assessment instruments, and connections to standards. **Adventures of the Agronauts: Mars Mission** uses inquiry methods, including role-play, to facilitate engagement and learning. In overview, the online experience will transform middle school students into “Agronauts” and convert their school or home computers into the instrument panels of spacecraft. By moving through each level of the Agronaut website, the young space researchers will acquire (and, in the context of the adventure, actually use) information about living systems, the Earth system, and the Solar System. This is current, standards-based knowledge that students need to learn in the middle grades. (Supported by a grant from the NASA North Carolina Space Grant).

**[IP.23] Engineered Rare Earth Nanoparticles for Alleviating Radiation Induced Injury.** Sudipta Seal\textsuperscript{1}, Soumen Das\textsuperscript{1}, Isabel L Jackson\textsuperscript{1}, Ram K Tripathi\textsuperscript{2}, Zeljko Vujaskovic\textsuperscript{1}. 1Advanced Materials Processing and Analysis Center and Nanoscience and Technology Center, University of Central Florida, Orlando, FL; 2Department of Radiation Oncology, University of Maryland School of Medicine, Baltimore, MD.

We have shown that engineered cerium oxide nanoparticles (CNPs) exhibit regenerative antioxidant activity. CNPs can scavenge ROS (superoxide radical, hydroxyl radical and hydrogen peroxide) and RNS (nitric oxide radical and peroxynitrite) efficiently both in vitro and in vivo model systems. This unique surface regeneration property of CNPs is due to very low reduction potential of the Ce\textsuperscript{4+/3+} redox couple. It is well know that ionizing radiation generates excessive reactive oxygen/nitrogen species in biological tissue (ROS/RNS) through Photoelectric, Compton and Auger effect. Recently, we have shown that CNPs protect from DNA damage of normal breast epithelial cells and preserve cell survival, however, did not show any protection towards breast cancer cell against 10 Gy radiation exposures. **In vivo** mouse model experiment showed survival of irradiated mice significantly increased in mice pretreated with 15mM (0.00001 mg/kg) CNPs (50% alive end of the experiment) as compared with control mice (50% alive on day 132). A similar study dealt with neck radiation mice model also showed decrease in apoptotic acinar cells and increase in salivary production in CNPs treated mice. CNPs have been also explored as radiation sensitization for radiation therapy. A two fold increase in ROS was observed in CNPs treated pancreatic cancer cell culture model (L3.6pl) after 30min and up to 24hr of post radiation exposure whereas a 50% decrease in ROS was observed in CNP treated normal pancreatic cells. **In vivo** pancreatic cancer model showed that the presence of CNPs significantly decreases tumor volume and weight compared to the radiation alone. Recently, we have shown a significant percentage (90%) of thorax irradiated animals survived in the CNPs treatment group when treatment starting 2hr after acute radiation exposure. These results suggest potential application of CNPs/nanotechnology toward the development of a product that will improve treatments available for radiation injury in radiation victims/radiation therapy for cancer.

We acknowledge NIH, NSF and NASA-Langley for financial support.

**[IP.24] Laboratory Instruments Available to Support Space Station Researchers at Marshall Space Flight Center.** B. Panda, S. Gorti, Marshall Space Flight Center, NASA.

A number of research instruments are available at NASA’s Marshall Space Flight Center (MSFC) to support ISS researchers and their investigations. These modern analytical tools yield valuable and sometimes new informative results from sample characterization. Instruments include modern scanning electron microscopes equipped with field emission guns providing analytical capabilities that include angstrom-level image resolution of dry, wet and biological samples. These microscopes are also equipped with silicon drift X-ray detectors (SSD) for fast yet precise analytical mapping of phases, as well as electron back-scattered diffraction (EBSD) units to map grain orientations in crystalline alloys. Sample chambers admit large samples, provide variable pressures for wet samples, and quantitative analysis software to determine phase relations. Advances in solid-state electronics have also facilitated improvements for surface chemical analysis that are successfully employed to analyze metallic materials and alloys, ceramics, slags, and organic polymers. Another analytical capability at MSFC is a magnetic sector Secondary Ion Mass Spectroscopy (SIMS) that quantitatively determines and maps light elements such as
Dynamics’ instrument will provide for the conditioning of samples: nucleation in macromolecular solutions. The ‘Soft Matter’ emulsions in space and the influence of particles thereon; the in these broad topics, International Teams aim to study foam or Operations Directorate, European Space Agency. and Astronaut Support Department, Human Spaceflight and Kufner, M. Martella and the science and industry teams, Utilisation instruments in ESA’s ELIPS programme. O. Minster, H. Ranebo, E. capabilities necessary to document the dynamic behaviour of the (4 types will be studied) as well as the advanced light scattering mixing and thermal control in individual in-orbit exchangeable cells. The instrument design allows in orbit exchange of units containing groups of individual cells or an individual cell and its dedicated support systems. The instrument should be operated in the Fluid Science Laboratory in Columbus as of 2016. The ‘Colloidal Solids’ instrument will provide for sample mixing and thermal control in individual in-orbit exchangeable cells (4 types will be studied) as well as the advanced light scattering capabilities necessary to document the dynamic behaviour of the samples. As baseline Dynamic Light Scattering at different angles, Small Angle Light Scattering in homodyne configuration and Time Resolved Correlation Spectroscopy will be provided. The implementation of Confocal Depolarised Dynamic Light Scattering for the characterisation of clusters will also be considered. The potential for scientific synergies with direct observations using NASA’s Light Microscopy Module will be fully exploited by the teams. Wherever technical feasible, dedicated cells will be made compatible with both instruments. A third instrument, ‘Vip-Gran’ to investigate granular gases in vibrated cells and stresses in compacted grains was also designed. It will undergo extensive scientific testing on parabolic flights in the coming years. The instruments are developed by European industry under ESA contracts.

[IP.25] Soft Matter, Colloids and Granular Matter research and instruments in ESA’s ELIPS programme. O. Minster, H. Ranebo, E. Kufner, M. Martella and the science and industry teams, Utilisation and Astronaut Support Department, Human Spaceflight and Operations Directorate, European Space Agency. In these broad topics, International Teams aim to study foam or emulsions in space and the influence of particles thereon; the physics of loosely compacted granular matter; colloids physics and nucleation in macromolecular solutions. The ‘Soft Matter Dynamics’ instrument will provide for the conditioning of samples: foaming of liquid-gas mixtures, emulsification of liquid-liquid mixtures or agitation of granular matter in dedicated cells and their conditioning. It will also provide for the optical diagnostics capabilities necessary to do their characterisation and monitor the dynamics of their coarsening with time. These include an overview camera and light scattering based diagnostics such as Speckle Variance Spectroscopy, Diffusing Wave Spectroscopy and Time Resolved Correlation Spectroscopy. The instrument design allows in orbit exchange of units containing groups of individual cells or an individual cell and its dedicated support systems. The instrument should be operated in the Fluid Science Laboratory in Columbus as of 2016. The ‘Colloidal Solids’ instrument will provide for sample mixing and thermal control in individual in-orbit exchangeable cells (4 types will be studied) as well as the advanced light scattering capabilities necessary to document the dynamic behaviour of the samples. As baseline Dynamic Light Scattering at different angles, Small Angle Light Scattering in homodyne configuration and Time Resolved Correlation Spectroscopy will be provided. The implementation of Confocal Depolarised Dynamic Light Scattering for the characterisation of clusters will also be considered. The potential for scientific synergies with direct observations using NASA’s Light Microscopy Module will be fully exploited by the teams. Wherever technical feasible, dedicated cells will be made compatible with both instruments. A third instrument, ‘Vip-Gran’ to investigate granular gases in vibrated cells and stresses in compacted grains was also designed. It will undergo extensive scientific testing on parabolic flights in the coming years. The instruments are developed by European industry under ESA contracts.

[IP.26] Red Light Effects on Blue-Light-Based Phototropism in Roots and Hypocotyls. K. Millar1, T. Sindelar2, J. Z. Kiss1. 1National Center for Natural Products Research, University of Mississippi, University Mississippi; 2Botany Department, Miami University, Oxford Ohio. Plant responses to environmental cues are multifaceted, complex, and many aspects still remain to be elucidated. These responses have been shown to share common players and to influence each other. The aim of this research was to clarify the involvement of red-light effects of blue-light phototropism in roots and hypocotyls of seedlings. Previous studies have shown a red light enhancement of blue-light phototropism in shoots and that this enhancement is mediated by the phytochromes. In contrast to the effects in shoots, we found that red light inhibits blue-light-based phototropism in roots of Arabidopsis seedlings in the Landsberg ecotype. Our studies also show that PHYA and PHYB play a role in the inhibition of blue-light phototropism in roots of Landsberg seedlings. However, this attenuation of blue-light phototropism was not seen in roots of Columbia ecotype seedlings. Roots of the Columbia seedlings displayed a significant enhancement of blue-light phototropism by red light pretreatment. Inhibition of blue-light phototropism also was observed in C24 ecotype seedlings, and this inhibition was not seen in a transgenic strain deficient in all phytochromes in the root only. Taken together, these data suggest that there is a difference in tropisms dependent on ecotype, and that for ecotypes that do display an attenuation of blue-light root phototropism by red-light, phytochromes are involved in the pathway. This study is one of very few to investigate red-light effects on blue-light phototropism in roots and serves as a ground study for our recent spaceflight experiment.


The Light Microscopy Module (LMM) presently on the International Space Station (ISS) is an enhanced laboratory microscope, a Leica RXA, capable of being operated in an automated mode with guidance from ground support staff. Its present core capabilities include a level of containment and white light imaging. Future capabilities under development include fluorescence microscopy and confocal microscopy. This presentation will visually summarize the hardware and software capabilities of the LMM. This will include pictures and descriptions of the:

- modified microscope
- LMM control box
- imaging cameras and data handling (upgraded in 2015)
- Auxiliary Fluids Container (AFC)
INVESTIGATOR AND STUDENT POSTER SESSION
TUESDAY, NOVEMBER 5, 2013 (6:00 PM – 8:00 PM)

- X-Y stage
- USAF test target
- biological sample modules (Petri and Opti-cells)
- physical science sample modules (specialty cells for temperature control, ACE-H in 2014, ACE-T in 2015, and E-grids, ACE-E in 2018)
- transillumination X-Y stage with a condenser and in-situ mixing (planned 2015)
- laser tweezers (proposed)

The LMM is a tool available for scientists that fly experiments on the ISS. It enables scientists to observe directly what is happening at a microscopic level in microgravity, an environment where sedimentation and gravitational jamming no longer mask the fundamentals of colloidal engineering, self-assembly, the natural manifestation of order out of disorder, and biology.

Supported by NASA.

**[IP.28] Rodent Specimen Biobanking for the Human Research Program (HRP).** April E. Ronca1,2, Julie Doostzadeh1,3, Paula M. Dumas1,4, Nathan E. Carrillo1, Jeffrey D. Smith1. 1Space Biosciences Division, NASA Ames Research Center, Moffett Field, CA 94035, 2Wake Forest School of Medicine, Winston Salem, NC, USA, 3Lockheed Martin, NASA Ames Research Center, Moffett Field, CA, USA

Fifty years into the space age, human and animal studies have specified physiological responses and adaptations to spaceflights of up to 6 months in Low Earth Orbit (LEO), and up to 12 days beyond LEO. With the transition from the era of the NASA Space Shuttle to the ISS and long-range plans for very long duration missions (>6 mo) to Mars or other destinations beyond LEO, it is clear that animal research in various scientific fields on Earth and in Space is critical to mission success. Here we describe a new rodent biobanking program, established at Ames Research Center, to support translational (rodent to human) science experiments for the Human Research Program (HRP) Health/Human Countermeasures (HHC) Element at Johnson Space Center. This effort builds upon the highly successful Ames Biospecimen Sharing Program launched in the 1960’s designed to maximize utilization and scientific return from unique animal specimens derived from rare, complex and costly NASA spaceflights. This new HRP collaboration leverages NASA Ames’ expertise in biospecimen sharing and focuses on acquiring rare specimens from important HRP investigations to ultimately be shared with qualified scientific experts. Hence, this program not only avoids waste of these specimens, but also advances scientific understanding of the physiological and molecular changes that occur while animals are exposed to the space environment. We have established a mobile operation serving HRP ground-based and flight experiments that is scalable to other projects as needed. Goals of the HRP Animal Biobanking Program are to: (1) Advance understanding of physiological responses and adaptations to the space environment utilizing animal models in support of the HRP mission, (2) Provide a repository of high quality, well preserved, and carefully archived and maintained biospecimens acquired from HRP studies by applying established best practices in the biobanking field, (3) Establish a database for gathering broad and comprehensive scientific information corresponding to these rare samples, including cutting edge tracking and archiving of structural and descriptive metadata. This program, modeled after human biobanking initiatives and best practices, will provide a rich archive of quality animal specimens relevant to a broad range of current and future scientific questions of interest to the NASA science community.

Acknowledgements: Human Research Program (HRP) Health and Human Countermeasures Program (HHC), Johnson Space Center; Peter Norsk, David Bauman, Carol Mullenax.


The thesis is addressed to the question of gravity-dependent gene expression in *Pisum sativum*. To determine the possible contribution of molecular chaperone genes in adaptation to the altered gravity conditions, we investigated gene expression of small heat shock proteins (sHsps) in etiolated pea seedlings under slow clinorotation (2 rpm). The sHsps are very diverse and variable in plants. Some higher plants have more than 30 individual sHsps genes and, unlike other groups, possess distinct sHsp subfamilies. Most of sHsp genes are highly sensitive to heat and other stressors. Others are selectively expressed in seeds and pollen, and a few are constitutively expressed. As a family, sHsps have a definite role in heat shock adaptation, but attributing specific effects to individual proteins has proved challenging. Methods of protein electrophoresis, immunodetection (Western blot) and RT-qPCR were used. Expression of five sHsp-genes belonging to the subfamilies with different subcellular localization: cytosolic-nuclear – *Pshsp17.1* (class CII) and *Pshsp18.1* (class-CII), chloroplast–*Pshsp26.2* (class-P), mitochondrial - *Pshsp22.9* (class-M) and endoplasmic reticulum – *Pshsp22.7* (class-ER) has been examined. Expression of housekeeping gene – *Actin* was used for normalization of data. Based on qPCR results, we demonstrate that transcription of sHsp genes in 5-day old etiolated pea seedlings dramatically increases under 30ºC and reached its maximum at 42ºC. These results confirm sHsp genes as temperature sensitive and special role of sHsp under heat shock conditions. More sensitive to the temperature elevation were sHsp genes, coding mitochondrial, chloroplast and ER-localized small heat proteins. Relative qPCR results demonstrate that altered gravity and temperature elevations have different effects on the sHsp: unlike high temperature, clinorotation does not lead to denaturation of cell proteins and, therefore, does not modulate sHsp gene expression.

**[IP.30] Prenatal exposure to either increased gravity or prenatal stress programs common, sexually dimorphic effects on adult bodyweight.** Lisa A. Baer1, Christina D. Tulbert2, Justin L. Bollinger3, 4April E. Ronca2,3,1. 1Space Biosciences Branch, NASA Ames Research Center, Moffett Field, CA, USA, 2Obstetrics & Gynecology, Wake Forest School of Medicine, Winston Salem, NC, USA, 3Surgical Sciences, University of Texas Medical School, Houston, TX, USA.

We tested the fetal programming hypothesis that male (but not female) Sprague Dawley (SD) rat pups conceived, gestated and born during continuous exposure to 2g centrifugation are characterized by adult overweight and increased anxiety responses. We compared 2g-exposed offspring to 1g (Earth gravity) controls (Study 1). In a separate study we analyzed the effects of a mild, variable prenatal stress regimen on adult body weight of male and female SD rats (Study 2). Study 1 Methods and Results: Young adult male and female (F0 or parent) rats were adapted to 2g centrifugation for one
week prior to mating and conception. Centrifugation was discontinued at birth then 2g and 1g neonates (F1) were fostered to non-manipulated, newly parturient dams. Adult body weights of 2g male rats were significantly greater than those of 1g males (p<.05). No differences were observed between 2g and 1g females. Study 2 Methods and Results: Prenatally Stressed (PNS) dams (F1) were exposed daily to three different stressors: (1) White Noise, (2) Strobe Light, and (3) Tube Restraint. Stressors were presented individually once per day on an unpredictable schedule (morning [0600-1200hr]; afternoon [1200-1800hr]; evening [1800-2400hr]) for one of three durations (15, 30 or 60min). Nonstressed (NS) control dams were handled briefly each day to match handling of the PNS dams. At birth, offspring (F1) were fostered to non-manipulated, newly parturient dams. Adult body weights of adult male but not female PNS offspring were significantly elevated over NS (p<0.05). Similar magnitude and developmental emergence of adult overweight in male but not female offspring was observed in both studies. Our findings provide evidence that either prenatal 2g exposure or mild prenatal stress alter the intrauterine milieu, thereby programming persistent, sex-specific alterations in adult body weight regulation. Future studies will focus on mild stress as a potential mechanism underlying 2g developmental programming. Supported by NIH Grant HD50201 and NASA Grant NNA04CK83.


Biosensors have many roles in space biology, including life support systems, space biology research, and exploration vehicles, to name a few. Biosensors are tools that provide real time measurement and high spatial resolution. State of the art biosensors immobilize recognition proteins together with catalytic nanomaterials such as graphene to improve sensor efficacy. Controlling nanomaterial properties during film formation is a major challenge outside the clean room. Standard electroplating techniques are capable of producing reliable thin films 0.5 to 5 μm thick. However, diffusion limitations and buildup of gaseous by-products limit the control of spatial patterning and therefore nanostructure performance. To resolve this problem, we have developed a custom pulsed sonication/electrodeposition system. The sonoelectrodeposition system was created using an Arduino™ microcontroller system connected to a bath sonicator and a DC power source. The sonicator process control will be available.


Within the ELIPS (European Programme for Life and Physical Sciences) programme of the European Space Agency great effort is made to realise the science defined in the research plan utilising the International Space Station (ISS).

One of the facilities will be the EML (Electromagnetic Levitator) which is a joint undertaking of the German Aerospace Center (DLR) Space Agency and the European Space Agency (ESA) and is planned to be installed in the European Drawer Rack (EDR) within the European Module “Columbus” on board the ISS. The facility is currently in its last stages of integration and testing and is scheduled to be uploaded with ATV-5 in 2014. EML offers a unique technique of containerless processing of metals and conductive materials with advantages that are straight forward, namely: no reaction of the molten material with the crucible and no heterogeneous nucleation on container walls. As a result high undercooling is achievable and the measurements can be performed over a large temperatures range. In comparison to the ground based EML facilities, the levitated drop is perfectly spherical under microgravity conditions and the positioning field is very low and therefore enables measurements in undisturbed molten samples and extension of the temperature range to even lower values. Those aspects guarantee a high level of accuracy of the measurements. During the experiment real time monitoring and process control will be available.

EML has the potential to evolve to a flagship of materials processing facilities which is also based on its large International Scientific Community, represented by more than 100 scientists. To guarantee the most efficient utilisation of this facility, an Investigator Working Group (IWG) consisting of representatives from each science project is the main forum to discuss and plan the experiments in particular with focus on the optimal utilization of the EML in terms of sample and budget sharing. Valuable input to support the utilisation plan is provided in the frame of the Ground Support Programme, i.e. evaporation measurement of the samples.


Since August 2009 the Materials Science Laboratory (MSL) is accommodated and in use in NASA’s Materials Science Research Rack 1 (MSRR-1). The MSL is dedicated to directional solidification experiments. For these experiments, ESA contracted EADS Astrium
Switched on and off. The interferograms acquired allowed to measure the Soret separation and to visualise vibration-induced convection. Later, a second experiment named COLLOID has been performed on the optical set-up modified into a Near Field Scattering (NFS) machine and the aggregation of colloidal particles has been correctly observed buy the NFS.

The latest studies aim to measure diffusion and thermodiffusion coefficients in ternary fluid mixtures in the framework of the DCMIX project, of which the first series of experiments has been performed and is currently being analysed by the team. The second series of experiments is currently being prepared to be uploaded to the ISS as well as the third series has been defined. For those investigations a cell array is filled with the experiment specific fluids and a thermal profile is applied to stimulate the diffusion process.

**[IP.35] The TRANSPARENT ALLOYS instrument for in-situ monitoring of solidification processes on board the ISS.** D. Voss¹, O. Minster². ¹HESpace bv for European Space Agency, The Netherlands, ²European Space Agency, The Netherlands, on behalf of ESA’s Science, Payload and Operations Team, Science Team and Space Industry.

In-situ observation of the solidification process is of great benefit to the materials science community to gain deeper understanding of the process dynamics. Within the ELIPS (European Programme for Life and Physical Sciences) programme of the European Space Agency the TRANSPARENT ALLOYS instrument is under development to support these investigations offering in-situ monitoring capability for transparent model substances. The project development is currently in Phase C/D and an engineering model is available. The instrument will allow to perform directional solidification experiments using the Bridgman technique. Four experiment types called CETSol, METCOMP, SEBA and SETA have been selected as experiment candidates for the TRANSPARENT ALLOYS instrument.

The science objectives to be investigated span over a wide range of solidification aspects, namely; Investigation of the pattern formation during solidification of multiphase alloys - SETA/SEBA project; The study of the Columnar to Equiaxed transition - CETSOL project; To gain deeper understanding of the Peritectic Reaction including the establishment of a microstructure selection map – METCOMP project; The samples are of flat, rectangular shape surrounded by a quartz glass crucible and are pulled through the Bridgman assembly at variable speeds. The temperatures of four heaters (two at each side) can be regulated independently. The main diagnostic element of the instrument is optical observation with high resolution. Two cameras are available to observe the liquid/solid interface behaviour morphology evolution between the hot and cold zones of the Bridgman assembly within the adiabatic zone. Two viewing angles can be used and scanning mode is available. The TRANSPARENT ALLOYS instrument is intended to be installed and operated in the Microgravity Science Glovebox (MSG) on the International Space Station (ISS). During the repeatable processing of the samples, near real time monitoring and control of the process parameters will be possible.
In-situ observation of metallurgical processes is of great benefit to Operations Team, Science Team and Space Industry. A method of accurately measuring the densities of high-temperature liquids by electromagnetic levitation (EML) technique has been developed and successfully flown on board the Sounding Rocket Maser 12. A second furnace offering isothermal behaviour is currently under development for this module to enable the investigation of exquai dendritic growth to fly on Maser 13. Since 2013, a set-up for solidification experiment can also be utilised for experiments on-board parabolic flights.

In addition to solidification process monitoring, metal foam processing has been investigated. A module (XRMONFoam) has been developed and successfully flown on Maser 11 in May 2008. Furthermore, diffusion measurements are of interest for the materials science community and a third XRMON module (XRMONDiff) was developed and flown on MAXUS 8 to study inter- and self-diffusion in Al-Ni, Al-Cu and Ge-Si samples. A re-flight is scheduled on MAXUS 9.

Results of in-situ investigations under microgravity conditions can be comparing to the results obtained with terrestrial X-ray investigations to directly pinpoint the effect of gravity on phenomena related to metallurgical processes without relying on studies with transparent model systems or post-mortem analysis of processed materials.

The Dusty Plasma Physics Facility (DPPF) is an instrument for the International Space Station (ISS) that has been proposed by the Jet Propulsion Laboratory (JPL). A dusty plasma is an ionized gas containing small particles of solid matter, which become electrically charged. They occur in the solar system, for example comet tails, the rings of Saturn, and the exosphere of the Moon at sunset. Dust grains become electrically charged due to collecting electrons and ions, or emitting electrons. Laboratory experiments with dusty plasmas allow the study of fundamental physics problems such as crystallization, phase transitions, phonons, nonlinear waves, instabilities, anomalous transport such as superdiffusion, and non-Gaussian statistics. They also allow geophysics experiments to simulate conditions on airless bodies such as asteroids and the Moon. For exploration, plasmas are of interest for dust mitigation strategies for extra-vehicular activities (EVA).

The Dusty Plasma Physics Facility is expected to support multiple scientific users. It will have a modular design, with a scientific locker, or insert, that can be exchanged without removing the entire facility. The first insert will be designed for fundamental physics experiments. Possible future inserts could be designed for other scientific purposes, such as experimental simulations of astrophysical or geophysical conditions or engineering studies. The design of the facility will allow remote operation from ground-based laboratories, using telescience.


Local flow and heat transfer around a single growing vapour bubble on a heated flat solid wall are simulated numerically with sharp interface representation. The transient thermal response of the wall is included with constant temperature condition on its back surface. The interfaces of vapour, liquid and solid phases are described by two level set functions with sharp interface representation. The ghost fluid method is employed for capturing the jump boundary conditions across the interface. Multi-cycle numerical simulation is required to relax the effect of un-physical initial conditions, particularly the assumed uniform temperature distribution inside the heater’s wall. Two criteria of nucleation point activation, namely
constant waiting time and constant superheat for re-activation of the nucleation point, are also used and compared for the computation of subsequent bubble cycles.

Because of the strong evaporation in micro-region, a sharp nucleation point, are also used and compared for the computation of the heat capacity of the wall. The distributions of local temperature and heat flux change with the move of the contact line. After the bubble detached from the wall, due to the backflow in the bulk liquid and conduction inside the wall, the lower temperature in this micro-region begins to rise up, until the re-activation of the nucleation point for the beginning of the subsequent new bubble cycle.

Supported by the National Natural Science Foundation of China under the grants of 11372327 and 10972225.

**[IP.40]** The Effects on Gene Expression on Human Hair and Mice Skin by Spaceflight. Masahiro Terada1, Shin Yamada2, Seki Masaya3, Rika Takahashi4, Akira Higashibata4, Hideyuki J. Majima5, Hiroshi Ohshima6, Yoshinobu Ohira4, Noriaki Ishioka1, Chiaki Mukai1. 1Japan Aerospace Exploration Agency, 2Advanced Engineering Services Co., Ltd, 3Kagoshima University, 4Osaka University.

The use of hair roots as experimental samples has many advantages, one of which is the fact that hair matrix cells actively divide in a hair follicle and sensitively reflect the physical conditions of the human body. Therefore, we focused on using hair root analysis to understand the effects of spaceflight on astronauts. In 2009, we started a research program focusing on the analysis of the same samples by a BD FACSAarray benchtop flow cytometer. Microflow1 results may pave the way for a permanent installation on the ISS supporting real-time, on-orbit life science analysis and biomedical diagnostic for crew members.

Supported by Canadian Space Agency (9F053-101538) and Institut National d’Optique.

**[IP.42]** Enhanced Capillary Height of Wetting Liquids in Reduced Gravitational Shielding under Microgravity Conditions. George D. Zouganelis1, Ioannis Gkigkitzis2, Ioannis Haranas3. 1Bournemouth and Poole College, Health and Medical Sciences, North Road, Poole, Dorset, BH14 OLS, e-mail: zouganelis@bpc.ac.uk; 2East Carolina University, Departments of Mathematics and Biomedical Physics, 124 Austin Building, East Fifth Street, Greenville, NC 27858-4353, USA; e-mail: gkigkitzisi@ecu.edu; 3York University, Department of Physics and Astronomy, 4700 Keele Street, Toronto, Ontario, M3J 1P3, Canada, e-mail: yiannis.haranas@gmail.com.

We study the capillary height of wetting in liquids by slightly modifying Ponorarenko’s result, a recently derived and observed t^{1/3} law, without omitting the corresponding gravity term. We find that \( h_{cm}(t) \approx 0.0985 h_{cm}(t) \), which corresponds to a 9% difference between the two models. Furthermore, to examine the effect of including gravity, we extend our approach to the surface of a planetary body (Earth) by including modifications to the gravitational field associated with its oblateness coefficient and rotation. We find that observations made on the planet’s equator would result in larger capillary heights than those at mid-latitudes and the poles. Similarly, analyzing the effect of reduced gravitational shielding on the capillary height under conditions of microgravity in experiments aboard orbiting spacecraft, we find that equatorial circular orbits would exhibit larger capillary heights than do equatorial elliptical orbits, and that increasing the eccentricity leads...
to decrease in capillary heights. Finally, as an example, we calculate the rate of change of the meniscus height in the time domain for various laboratory conditions on the surface of Earth and in space. We show that observations at the terrestrial equator will exhibit the largest time rates of change in meniscus height. On board a spacecraft, we show that circular equatorial orbits would exhibit the largest time rates of change, while elliptical orbits would exhibit smaller time rates that decrease as the eccentricity increases.

**Student Posters:**
6:00-7:30 pm – Even numbered posters
7:30-9:00 pm – Odd numbered posters

**[SP.1] Differential Signal Expression of Arabidopsis GFP Reporter Gene Constructs on Orbit.** E.R. Schultz1; A-L Paul1,2; and R.J. Ferl1-3.

1Program in Plant Molecular and Cellular Biology; 2Horticultural Sciences Department; 3Interdisciplinary Center for Biotechnology Research, University of Florida, Gainesville, Florida 32610 USA.

Green fluorescent protein (GFP) is commonly used as a reporter gene in many applications of biology. Traditionally, experiments have looked at the redistribution of the signal, along with its appearance or disappearance among the conditions tested. In this experiment, average GFP intensity of two reporter genes was quantified in Arabidopsis seedlings over time in spaceflight (and in appearance or disappearance among the conditions tested. In this study, we have looked at the redistribution of the signal, along with its appearance or disappearance among the conditions tested. In this example, average GFP intensity of two reporter genes was quantified in Arabidopsis seedlings over time in spaceflight (and in the terrestrial environment). We show that observations at the terrestrial equator will exhibit the largest time rates of change, while elliptical orbits would exhibit smaller time rates that decrease as the eccentricity increases.

This work was supported by NASA grants NNX09AL96G, NNX07AH270 and NNX12AN69G to RIF and A-L Paul.

**[SP.2] Disruption of Cell Growth and Proliferation Induced by Simulated Microgravity on Synchronous Plant Cell Cultures.** Khaled Youssef, Jack J.W.A. van Loon*, Raul Herranz and F. Javier Medina. Centro de Investigaciones Biológicas (CSIC), Ramiro de Maeztu 9, 28040 Madrid, Spain. fjmedina@cib.csic.es, 
DESC (Dutch Experiment Support Center), VU University Medical Center & Academic Centre for Dentistry Amsterdam & MMG-Lab, ESTEC, European Space Agency, Noordwijk, The Netherlands.

Understanding the physiological processes occurring in plant cells under the space environment is crucial to successfully undertake space exploration strategies. On-orbit microgravity environment seems to dissociate cell proliferation from cell growth in seedling root meristems, particularly increasing cell division rates and decreasing cell growth (measured as a reduction of nucleolar activity). Whereas root meristem biomass is limited, a cell culture system produces higher yields of proliferating cells and allows the accomplishment of sequential flow cytometry cell cycle studies, even using cell synchronization, which has never been approached before in microgravity. Otherwise, gravity sensing and response in cell cultures must occur in single cells, without the involvement of specialized organs or tissues.

Here, we describe the first successful use of synchronized cells to characterize different cell cycle phases under simulated microgravity obtained in a Random Positioning Machine (RPM), a ground-based facility capable of averaging the gravity vector, suppressing in practice its effects on the living organisms. Cell synchronization was achieved in a suspension culture by arresting cells in late G1/S by 24h aphidicolin incubation. Cells were then immobilized in agarose, in order to be exposed to inertial forces during the RPM rotations. Sampling at different times allowed isolation of different cell cycle-phase-enriched populations. An increase on the cell proliferation rate under simulated microgravity was observed. The cell cycle was about 2-3 hours shorter in microgravity, mainly due to a decrease of the G2/M phase duration. Regulation at the G2/M checkpoint was disrupted, as inferred from the lower levels of cyclin B1. Ribosome biogenesis, measured by nucleolin expression, nucleolus area and distribution of subnucleolar components, was depressed after the RPM treatment. Chromatin organization was also affected; a lower level of transcription, together with abnormal distribution of chromatin masses was detected under simulated microgravity. Epigenetic processes, involving DNA methylation and histone acetylation, could be also involved. In conclusion, cell cultures demonstrated and extended the hypotheses suggested from our previous results with Arabidopsis seedlings concerning decoupling of cell proliferation and cell growth under microgravity. Interestingly, these alterations are based on a system of gravity sensing and response independent on the root gravitropic mechanism.

**[SP.3] A Gradient of Extracellular Nucleotides Directs Polarization in Early Growth and Development of Ceratopteris Spores.** Ashley E. Cannon, Greg Clark, Stanley J. Roux. Section of Molecular Cell and Developmental Biology, The University of Texas at Austin, TX 78712, USA.

Polarization is essential for most cells during development. Many studies have shown that gravity directs the polarization of...
Ceratopteris spores and that a visible representation of this effect is the emergence of a rhizoid pointing downward about 72 hours after germination begins. This polarized event requires a trans-cell calcium current that starts with calcium entering at the bottom of the spore before exiting through the top and runs parallel to the vector of gravity. Recent data have shown that extracellular nucleotides can affect the gravity response and the rate of rhizoid growth in Ceratopteris spores. Additionally, a purinoceptor antagonist, pyridoxal-phosphate-6-azophenyl-2, 4-disulfonate (PPADS), can affect the gravity response even if it is only present during the first ten hours of germination. These data suggest that extracellular nucleotides play a role in regulating the gravity response and growth in Ceratopteris spores just as they do in Arabidopsis thaliana. Many studies have shown that gravity can induce the opening of stretch activated channels and that the opening of these channels permits the release of ATP. These results led us to hypothesize that as a result of gravity, mechanosensitive channels preferentially open along the bottom of the spore and release ATP. This asymmetrical distribution of extracellular ATP could potentially direct where calcium enters the cell. Also, blocking extracellular ATP receptors with PPADS blocks the ability of gravity to direct the steps necessary for the downward growth of rhizoids. When spores are exposed to an artificial gradient of extracellular nucleotides, the rhizoids tended to grow towards the source of the gradient. Collectively, these results support the hypothesis that the preferential release and subsequent gradient of extracellular nucleotides is involved in the polarization of Ceratopteris spores. Information about the early signaling events that lead to gravity directed polarization will aid in the development of systems and techniques that future astronauts can use to grow plants in space. This will become important on long-term missions and during extended spaceflight.

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Roots respond to reorientation by differential elongation of roots and shoots. Although this gravitropic response is commonly measured, the typical reorientation is perpendicular to the gravity vector (90 degree reorientation). The objective of this study is to find the minimum angle that induces curvature. We reoriented the roots in 10 degrees increments relative to vertically grown control seedlings. When 40 hour old, vertically grown roots were reoriented, no distinct curvature was observed unless reorientation exceeded 20 degrees. Because curvature is the result of changes in auxin transport, we investigated the relationship between the displacement angle and the polarity of basipetal auxin transport. 3H-IAA containing agar blocks were applied to reoriented roots and the transport rate measured as the amount of radioactivity that reached the maturation zone of roots. Auxin transport was higher in vertically grown roots compared to reoriented roots. Auxin transport decreased as the angle of reorientation increased. These data suggest that auxin sensitivity affects the threshold of curvature response.

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[SP.5] An Extraterrestrial Approach to Gene Discovery. Natasha J. Sng¹, Anna-Lisa Pau²,³, and Robert J. Ferl¹,³. Program in Plant Molecular and Cellular Biology; ²Horticultural Science Department; ³Interdisciplinary Center for Biotechnology Research, University of Florida, Gainesville, Florida, USA.

Plants are sessile organisms that have evolved many different mechanisms to aid in their ability to respond and adapt quickly to changes in their environment. Sending plants into orbit provides a unique opportunity to observe how plants adjust to the novel environmental features of spaceflight, such as the lack of gravity. In a recent study, we found that Arabidopsis thaliana (Arabidopsis) responded to spaceflight with organ-specific differential expression of hundreds of genes as compared with ground controls - leaves, hypocotyls, and roots each displayed unique patterns of response. Arabidopsis is a model plant that has been fully sequenced and well characterized on many levels. Yet, there are numerous genes present in the Arabidopsis genome that encode proteins of unknown function. Over 100 of these unknowns are among the genes that are differentially expressed by at least 2-fold in response to spaceflight in an organ specific manner. Many of the unknowns have interesting and complex patterns of expression; several are highly induced or repressed in one plant organ, while being virtually unchanged in the others organs, whereas some of these genes are induced or repressed in two or across all organs.

The spaceflight environment could thus provide unique clues to the possible role of these genes of unknown function in gravity sensing or in some of the other categories highly represented in the spaceflight transcriptome, which includes cell wall remodeling, auxin signaling and plant developmental processes. For instance, we identified a gene (Mutant 63) that showed significant upregulation in roots by 12 fold change in spaceflight. Knock-out mutant 63 grown on vertical plates appeared similar to the Col-0 wild-type ecotype. However, growing Mutant 63 on a 45 degree slanted plate, altering the plant’s perceived gravity vector, resulted in these plants having a reduced biomass phenotype. By generating a variety of
transgenic plants to genes identified by spaceflight, and exposing them to altered gravity conditions such as slanted plates or clinorotation, we intend to elucidate unknown gene functions. This work was supported by NASA grants NNX09AL96G, NNX07AH270 and NNX12AN69G to RJF and A-L Paul.


Plant growth depends on water, which is in short supply for space missions and future settlements on the moon or mars. Unlike their reproductive structures such as seeds, spores, and pollen, vegetative tissues typically do not survive extended water deficit conditions. However, certain plant groups known as ‘resurrection plants’ have developed mechanisms to withstand desiccation. Polypodium polypodioides, an epiphytic fern, survives extended periods of desiccation recover even after repeated drought cycles. The mechanisms that allow these plants to tolerate desiccation are not well understood but useful for generating plants that can grow under reduced water conditions. To assess the dehydration tolerance of Polypodium, we are in the process of analyzing the transcriptome by RNA-Seq and measured the levels of two stress induced molecules abscisic acid (ABA) and Reactive Oxygen Species (ROS) over the course of dehydration and compared these levels with desiccation sensitive Brassica rapa. With decreasing water content the ABA content increased and ROS content decreased in Polypodium in relation to Brassica. These findings suggest that Polypodium contains integrated system of signaling pathways that may be up-regulating desiccation tolerant genes, which are absent in desiccation sensitive plants.

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Plants constantly align their growth axes parallel to the gravity vector. The sensing and response to changing gravity vector affects genes. We examined these changes in Brassica rapa roots that were reoriented and clinorotated. Gene expression levels related to the actin cytoskeleton (ACT7 and ADK1) and auxin transport (PIN1, PIN3, AGR1, ARG1) were assessed in B. rapa roots grown for 42 hours and then reoriented to 90° for 1, 2 and 4 hours or imbibed and clinorotated vertically or horizontally for 42 hrs at 1 rpm. After treatment, roots from 25 seedlings were cut into three sections, the root cap, elongation zone, and maturation zone, combined and used as one sample. RNA was extracted and reverse transcribed and analyzed by quantitative PCR. The results show that gene expression fluctuates in response to duration of reorientation and direction of clinorotation. Expression also varies along the length of the root; however, these changes are gene specific. Because of the variability of the expression profile, analyses that are based on the entire root miss important and tissue specific changes in gene expression. Supported by NASA grant NNX10AP91G and LaSPACE GSRA.


We are examining the possible elicitation of resveratrol, an antifungal antioxidant, and related stilbenoids from Vitis callus culture in simulated microgravity using a Random Positioning Machine (RPM; “3-D” clinostat) to perform random changes in orientation faster than the response time to the gravitational stimulus. The callus stage of tissue culture is optimal for these studies, being small in size, easily manipulated, & readily extractable. These data are pertinent to understanding the mechanism by which resveratrol and corresponding precursors and metabolites aid in prevention and/or resistance to fungal infection in grape and in other species capable of synthesizing stilbene derivatives in response to bacterial, fungal, and viral pathogens. Reducing fungicide applications may decrease environmental consequences associated with fungicides. Plants with higher resistance to fungal infections used as models in space research payloads could benefit in preventing such outbreaks in closed environmental systems.

By removing or reducing the gravity vector (g-force), information can be obtained concerning plant tropisms and physiologic processes influenced by gravity. The synthesis of plant metabolites has been studied for over a decade in simulated microgravity and hypergravity; cell cultures of Taxus species exposed to microgravity exhibited overproduction and release of free- and bound-taxol (paclitaxel; onxal) into the culture media. The effect of microgravity on taxol synthesis is the basis of the hypothesis that microgravity may alter resveratrol & stilbenoid synthesis. Examination of microgravity effects on resveratrol biosynthesis could provide insights into the control of plant infections and disease in closed environmental systems associated with extended space missions and methods of production of resveratrol during extended space missions.

A RPM was constructed with 1.5 inch steel conduit. Two cardanic frames, with base, were constructed in our laboratory by adapting designs previously created by ESA/ESTEC and DESC researchers. Vitis callus cultures were monitored using time-lapse video and custom analysis software to obtain estimates of growth rate of 1 g controls and simulated microgravity cultures. Resveratrol and stilbenoids were extracted from cultures exposed to simulated microgravity for various periods of time and quantified using a Waters Acquity UPLC system equipped with a PDA detector and confirmation by mass spectrometry.


With increased explorations into the outer realms of space, astronauts are put under new and unexplored stresses. Although there has been significant research conducted to investigate the effects of microgravity on many human biological mechanisms, there has been very little research conducted to better understand the effects of microgravity on the Cori cycle. The Cori cycle is responsible for the conversion of lactic acid in the muscle to pyruvate by way of the liver, which causes the production of the Adenosine triphosphate (ATP). ATP is used by muscle cells as an
energy source for muscular contraction during muscular activity. In order to study this process we observed the reaction between Pyruvate and Nicotinamide adenine dinucleotide (NADH) in the presence of lactate dehydrogenase (LDH) to form Lactate and NAD⁺. Using a spectrophotometer, we measured the change in absorbance as NADH was consumed while the reaction occurred. Microgravity measurements were very recently made on board NASA’s microgravity research aircraft as part of their Reduced Gravity Education Flight Program. This highly competitive program provides select undergraduate students the opportunity to fly experiments on their “0-g” aircraft. Flight data will be compared to ground truth measurements of the reaction made in 1-g. We present the findings of our investigation as well as future plans.

The Weightless Lumbee research team is supported by grants from the North Carolina Space Grant Consortium and UNCP Research Initiative for Scientific Enhancement (RISE).


Department of Plant and Microbial Biology, NC State University, Raleigh, NC, USA; 2Department of Biology, Marshall University, Huntington, WV, USA; 3Research and Graduate Education, University of North Carolina General Administration, Chapel Hill, NC, USA.

Understanding the effect of microgravity on plant growth is crucial as long duration space missions become a reality. The phosphoinositide pathway, mediated by the signaling molecule inositol 1,4,5-trisphosphate (InsP3), is involved in plant responses to environmental cues, including gravity. The Plant Signaling experiment was designed to compare the response of transgenic Arabidopsis seedlings exhibiting altered InsP3-mediated signaling and wild type seedlings under microgravity conditions. The experiment was conducted in the European Modular Cultivation System (EMCS) onboard the ISS which houses two centrifuges within a single chamber. During the experiment, one centrifuge was kept stationary at micro g, while the other simulated 1g. Seedlings were grown for five days and growth was monitored by images obtained every six hours. Preliminary measurements of downlinked images indicate that there were no significant differences in total root length after five days between the different lines or treatments. Interestingly, the microgravity seedlings appear to have more disorganized growth. However, poor image resolution and variable camera positioning has made it difficult to accurately quantify these subtle changes in growth and to automate the measurement process. As manual image analysis will be required, it is critical that user error is minimized. My plan is to create a single annotated image by sequentially overlaying and aligning individual time points on the final image using ImageJ. Using the annotated image for analysis will reduce error and enable accurate measurement of root growth rates and deviation from vertical over the experimental time course.

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1Biomedical Engineering, University of North Carolina Chapel Hill; 2Mechanical Engineering, University of Colorado at Boulder; 3Clemson University; 4Beth Israel Deaconess Medical Center; 5Harvard-MIT Division of Health Sciences and Technology; 6Amgen.

Skeletal unloading during spaceflight reduces bone volume and mineral density; however, how this loss translates to functional changes in strength and stiffness in the proximal femur is not well understood. This study uses finite element modeling (FEM) that replicates physiological loading of the femoral neck in mice flown on STS-135 to assess bone stiffness changes from spaceflight and sclerostin antibody (Scl-Ab).

Thirty mice were flown on Space Shuttle Flight STS-135 for 13-days (FL). Half the mice were treated with vehicle (n=15) and half were treated with a Scl-Ab (n=15). Corresponding ground control (GC) groups were similarly treated. Subject specific FE models were meshed from each microCT mouse image (down sampled from 10 to 20µm resolution) for a 3.25mm proximal femur segment taken from the top of the femoral head. Bone was segmented using the identical threshold previously used in the microCT analysis of the STS-135 femurs. All bone elements were modeled as linear elastic (E=100GPa, v=0.3). A 50µm downward displacement was applied to the entire femoral head in order to isolate loads to the femoral neck.

This loading configuration differs from the corresponding mechanical testing performed on the femurs. The mechanical tests are susceptible to significant deformations in the femoral head in addition to the femoral neck. FEM of the proximal femur found a 10% decrease in stiffness in the FL mice compared to the GC mice. Scl-Ab treatment resulted in an increased stiffness by 20% in the FL and 23% in the GC. Linear regression found significant correlations (P<0.01) between the FEM stiffness and the femoral neck stiffness, fracture load, and force at maximum load found from mechanical testing. The unloading environment of microgravity caused a significant loss of femoral neck stiffness in the proximal femur. Scl-Ab prevented the loss of bone strength, and increased femoral neck stiffness in both FL and GC mice. The absolute stiffness values from FEM were greater than those measured with mechanical testing due to the different boundary conditions and the low bone density in the femoral head observed from microCT. The experimental boundary conditions must be considered when interpreting femoral neck strength.

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weaned male Wistar rats were pair-fed either normal powdered diet or the same diet containing 1% β-guanidinopropionic acid (β-GPA) for 8 weeks. Half of the animals were hindlimb-suspended for 10 days at the end of experimental period. Contractile properties, in situ, were measured in soleus of anesthetized rats. And fiber phenotypes were measured in soleus. Unloading-related shifts toward fast-twitch type in both contractile properties and fiber phenotype, seen in the control-diet group, were reversed by feeding β-GPA, which decreases high-energy phosphate contents and stimulates ATP synthesis in muscle. However, beneficial effects of β-GPA feeding were not observed in terms of the prevention of unloading-related decrease of maximal tension development and muscle mass. It is indicated that speed-related contractile properties and fiber-phenotype of skeletal muscle are regulated by metabolic factor, regardless of mechanical and/or neural stimuli. It was further suggested that the muscle mass and maximal tension development are influenced by mechanical and/or neural stimuli.

**[SP.13] Effect of Myostatin Inhibition and Microgravity on L5 Lumbar Vertebrae Trabecular Bone Microarchitecture in Mice.**

Stefanie M. Gonzalez1, Alicia M. Ortega2, Eric W. Livingston3, Eric Jiao4, Xiaolan Zhou, John Lu5, Louis S. Stodieck6, Ted A. Bateman3, H.Q. Han3, Virginia L. Ferguson1. 1Department of Aerospace Engineering Sciences, Bioastronautics University of Colorado Boulder, 2Department of Biomedical Engineering, University of Colorado Boulder, 3Department of Mechanical Engineering, University of Colorado Boulder, 4Department of Biomedical Engineering, University of North Carolina-Chapel Hill, 5Amgen Inc., One Amgen Center Dr., Thousand Oaks, CA, USA

Musculoskeletal degeneration is a major concern during long duration spaceflight missions due to loss of 1-2% average bone mineral density per month and about 30% loss in the isokinetic strength in muscles. Previous studies have examined countermeasures based on modifying the factors that directly affect bone formation/resorption. However, a countermeasure that prevents both muscle and bone degeneration has not been well established. Thus, a genetically engineered decoy myostatin inhibitor (MI, a negative regulator of skeletal muscle) may protect against muscle atrophy and bone loss. To study the combined effects of MI in microgravity, the microarchitecture of trabecular bone in the L5 lumbar vertebrae of 9-week old female C57BL/6N mice was studied. Mice were flown on STS-118 for 12.7 days and were divided into four groups: ground vehicle (GV, n=12), ground drug (GD, n=12), flight vehicle (FV, n=11), and flight drug (FD, n=11). Micro-computed tomography was used to quantify properties including bone volume fraction (BV/TV), trabecular thickness (Tb.Th), trabecular separation (Tb.Sp), trabecular number (Tb.N), and connectivity density (Conn.Den); differences between groups were tested using 2-way ANOVA followed by a Tukey post-hoc test. Spaceflight (FV vs. GV) significantly decreased BV/TV (-13.9%) and Tb.Th (-10.0%), with no measurable change in Tb.Sp. In contrast, MI treatment significantly increased BV/TV (+18.2%) and Tb.Th. (+9.9%) (for FV vs. MI), with no significant change in Tb.Sp. On ground MI also significantly increased BV/TV, Tb.Th, and Tb.Sp by +14.1%, +7.3%, and +5.9% respectively (GV vs. GD). Tb.N and Conn.D remained unchanged with spaceflight or MI (ground or SF). MI treatment mitigated SF-induced bone loss, where measures of trabecular microarchitecture negatively impacted by SF remained at GV levels in the FD mice. Collectively, these data reveal the effectiveness of the myostatin inhibitor in mitigating deleterious effects of spaceflight on bone microarchitecture. Thus, MI should be explored as a potential countermeasure to maintain skeletal structure and prevent muscle degeneration during long duration space missions.

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R. E. Harvey and R. M. Yoder. Department of Psychology, Indiana University-Purdue University, Fort Wayne, IN, USA.

Optimal task performance within an environment often requires some form of navigation. The strategy used to guide navigation is typically well-suited to the environment, and most species are able to switch to a different strategy when task demands or environmental conditions change. However, our studies in otoconia-deficient mice suggest that two common navigation strategies, landmark navigation and path integration, depend on graviception. This requirement poses a problem for human space travel because gravity-dependent strategies do not accurately guide navigation in microgravity. An accessible alternative strategy may therefore improve navigation accuracy in microgravity environments. To this end, we tested whether prior training on one navigation task could improve performance on another task in mice that lack the ability to perceive gravity. Otoconia-deficient tilted mice and their heterozygous control littermates were pretrained on a radial maze discrimination task in light or did not receive this training prior to performing a Lashley-III maze task in darkness. The radial maze consists of six walled arms radiating from a central platform, and optimal performance depends on a landmark navigation strategy. The Lashley-III maze consists of four walled alleys that lead from a start box to a goal box, and optimal performance depends on a path integration strategy. Non-pretrained control mice performed better than non-pretrained tilted mice, although both groups showed performance improvements across trials. Pret raining improved performance for both control and tilted mice. Importantly, pretrained tilted mice performed nearly identical to pretrained control mice, suggesting pretraining eliminated the Lashley-III maze deficits associated with impaired gravity perception. Otoconia-deficient tilted mice, which are impaired at landmark navigation and path integration, adopted an alternative navigation strategy that enabled them to overcome their path integration deficits. These results suggest that pretraining with alternative strategies may be beneficial for navigation in microgravity environments.

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**[SP.15] Comparison between Botulinum Toxin-Induced Muscle Paralysis and Hindlimb Unloading as Disuse Models.**

R. E. Elman1,2, D. J. Grasso1, M. van Vliet1, D. J. Brooks1, J. M. Spatz1,2, C. Conlon1, M. L. Bouxsein1,3. 1Center for Advanced Orthopaedic Studies, Beth Israel Deaconess Medical Center and Harvard Medical School, Boston, MA, USA; 2Health Sciences and Technology, Massachusetts Institute of Technology, Cambridge, MA, USA; 3Department of Orthopedic Surgery, Harvard Medical School, Boston, MA.
Bone receives mechanical stimulation from two primary sources, muscle contractions and external gravitational loading, but the relative contribution of each to bone maintenance is not well studied. Thus, we investigated the relative effects of paralysis and unloading on changes in muscle mass, bone mass and microarchitecture.

Adult female C57BL/6J mice (12 wks old) underwent one of the following (n=10/group): botulinum toxin A (BTX) injection, hindlimb unloading (HLU), both HLU and BTX (HLU+BTX), or no intervention. BTX-treated groups received a unilateral IM injection to the quadriceps and calf muscle groups (2U/100g total dose) three days before HLU; all mice were sacrificed after 21 days.

HLU, BTX and HLU+BTX all led to significant loss of leg muscle mass, hindlimb BMD and bone microarchitecture relative to controls, while generally the combined HLU+BTX intervention had the most detrimental changes in bone and muscle. As an example, controls gained BMD (+4.6%, p<0.001 vs. baseline) while HLU mice lost BMD (-4.9%, p<0.01). BTX-treated mice lost even more BMD in their injected leg (-19.1%, p<0.001), and the most severely affected were the HLU+BTX group with a -30.2% loss of BMD in their injected leg (p<0.001) or 6-fold more than with HLU alone. Unexpectedly, we found a strong systemic effect of BTX affecting the uninjected (contralateral) leg that led to large BMD losses (-5.2% and -17.8% for BTX and HLU+BTX, respectively, p<0.05) and significant deficits relative to untreated controls in muscle mass (-25.2% BTX vs. control; -30.3% HLU+BTX vs. HLU) and trabecular bone volume (-24.0%, BTX vs. control; -52.8% HLU+BTX vs. HLU). The magnitude of this indirect effect was comparable to the direct effects of BTX treatment and HLU alone. This confounding factor hinders our ability to conclude whether muscle forces or external gravitational forces contribute more to bone maintenance, but it appears that BTX-induced muscle paralysis was more detrimental to muscle and bone than hindlimb unloading. In light of this, untreated controls should be included in future BTX studies to gauge the presence of indirect. Our data indicate that BTX may affect bone through mechanisms other than direct loading.

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**[SP.16] Responses of Circulating MicroRNAs to Hindlimb Unloading and Reloading in Mice.**  Miho Suzuki1, Yoshitaka Ohno2, Tatsuro Egawa1, Akihiko Ikuta1, Shingo Yokoyama1, Ayumi Goto1, Tomotaka Ohira1, Takao Sugiyama1, Yoshinobu Ohira4, Toshitada Yoshioka1, Katsumasa Goto1. 1Department of Physiology, Graduate School of Health Sciences, Toyohashi SOZO University, Aichi, Japan; 2Laboratory of Physiology, School of Health Sciences, Toyohashi SOZO University, Aichi, Japan; 3Department of Health and Sports Sciences, Yamaguchi University, Yamaguchi, Japan; 4Graduate School of Medicine, Osaka University, Osaka, Japan; 5Hirosaki Gakuin University, Aomori, Japan.

MicroRNAs (miRNAs) are small (~22 nucleotides) noncoding RNAs, which play important roles in the regulation of gene expression at the post-transcriptional level. Recently, it was reported that some miRNAs in blood were established as biomarkers for cancer, liver injury, and heart failure. miRNAs are released from cells through an exosomal-mediated pathway, suggesting that circulating miRNAs are packaged in exosomes. However, role of circulating miRNAs in skeletal muscle plasticity remains unknown. In the present study, we investigated the responses of plasma miRNAs to hindlimb unloading-associated atrophy and reloading-associated regrowth of skeletal muscle. Ten-week-old male mice (C57BL/6J) were used. All mice were housed in a vivarium room with 12:12-h light:dark cycle and ~23°C and ~50% temperature and humidity, respectively. Solid food and water were provided at libitum. Mice were randomly divided in two groups; control and unloaded. Unloading and reloading on soleus muscles were induced by 2 weeks of hindlimb suspension and ambulation recovery, respectively. Samples of blood, from the abdominal portion of vena cava, and soleus muscles were performed in mice under anesthesia with i.p. injection of sodium pentobarbital (5 mg/100 g body weight). Soleus weight relative to body weight was decreased following suspension, and was increased following recovery (p<0.05). Large increases (>10-fold) in miR-401, miR-3110, miR-135a-2*, and miR-708 were observed following suspension, compared with the level of control. In addition, miR-150, miR-153*, miR-3071, miR-224, and miR-208a-5p were increased during the recovery (> 4-fold). On the other hand, 16 miRNAs, such as miR-3071 and miR-547, were decreased by the suspension. During the recovery, many miRNAs were decreased, compared with the level of control. It was suggested that analyses of plasma miRNAs may be useful to estimate the responses of skeletal muscle properties.


Effects of exhaustive cycling exercise in 90° head-up (HU) and 6° head-down (HD) position on the total counts and percentage of each type of white blood cells (WBCs) in venous blood were studied in 5 healthy male subjects. The estimated mean (±SEM) resting blood volume in the lower leg of subjects at HD position was decreased by 68.0 ± 2.6 ml vs. HU position (p<0.05). The maximum exercise time was less than at HU position. Significant increase of total WBC counts was noted when the oxygen consumption was 20 and 13 ml/min/kg during exercise in HU and HD position, respectively. The absolute number of each type of WBCs, except eosinophils, was also increased gradually in response to the elevation of work load. However, the increase of the % distribution was noted in lymphocytes and large unstainable cells only. The % distribution of monocytes, eosinophils, and basophils was relatively stable. And that of neutrophils was significantly decreased following the elevation of work load. It was indicated that leg exercise with inhibited blood distribution caused pronounced increase of lymphocytes among the WBC population, although the precise mechanism responsible is still unclear.

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Following spaceflight, astronauts appear to be immunocompromised and are subject to various alterations of immunological processes that increase the susceptibility to minor infections. The human microbiome outnumbers host cells by several orders of magnitude and may act either as a protective barrier or as potential pathogens. Certain non-pathogenic microorganisms elicit specific immunological responses. On Earth, axenic organisms may exhibit compromised innate immune systems and increased disease progression. The extent to which commensal bacteria alter immunity due to spaceflight has yet to be investigated. In space, it may be that altered immunity accompanies a change in the composition of the microflora. The effects of spaceflight on the microbiome can be evaluated using the model organism *Drosophila melanogaster* (fruit fly). After spaceflight, *D. melanogaster* show suppression of the innate immune system resembling some of the changes seen in humans. Additionally, fruit flies have a well-characterized microbial flora. The goal of this project is to examine if the exposure to hypergravity is accompanied by a change in microflora composition. *D. melanogaster* were exposed to a 3g environment to mimic hypergravity faced upon atmospheric exit and re-entry. Prolonged exposure to hypergravity produced a depression in antimicrobial peptides (AMPs) associated with the immune deficiency (imd) pathway. AMPs associated with the Toll pathway and oxidative stress genes displayed no significant decrease in gene expression. After a nine day incubation with adults, the whole-body composition of the microflora was dominated by *Acetobacter aceti* and appeared independent of the gravitational environment. The larvae and food had greater bacterial diversity and appeared independent of the gravitational environment. This research was supported by the Space Life Sciences Training Program (SLSTP) at NASA Ames Research Center, Lockheed Martin, and by the NASA funded grant NNH09ZTT003N/FSB09PROP-0022 to S. Bhattacharya.

**[SP.18]** The Effects of Hypergravity on *Drosophila melanogaster* Microflora Composition, Immunological Response, and Oxidative Stress.

**[SP.19]** Whole Genome Re-sequencing of Low-Pressure (LP) Evolved *Bacillus subtilis* Identifies LP Adaptive Mutations.


Low-pressure (LP) environments are not represented on Earth, but the ability of organisms to survive under hypobaric conditions is highly relevant to the field of Astrobiology. Specifically, for a terrestrial microorganism to grow at or near the surface of Mars (i.e., forward contamination, a concern of NASA Planetary Protection regulations), it would have to overcome the hypobaric environment on the surface, which averages ~0.7 kPa. (By comparison, the atmospheric pressure at Earth’s sea level is ~101 kPa.) Results from previous experiments indicated the existence of an LP barrier for the growth of many terrestrial bacteria of ~2.5 kPa, a pressure not represented on the Earth’s surface, but still 3-4x higher than exists on the surface of Mars. To test the hypothesis that microbes could evolve the ability to grow better at LP, we propagated wild-type *Bacillus subtilis* strain WN624 for 1,000 generations at 5 kPa, a pressure at which it grows very poorly, and isolated a strain called WN1106 that showed increased growth at 5 kPa, as well as an increased fitness at 5 kPa compared to the WN624 ancestral strain. Whole genome re-sequencing using the Illumina platform was conducted on both ancestor and the LP-evolved strain and the resulting genomes and compared to the reference genome of *B. subtilis* strain 168. To date, bioinformatics analysis of the data have located 6 single nucleotide polymorphisms (SNPs) causing missense mutations, and one Insertion / Deletion mutation (InDel) located in coding regions of strain WN1106’s genome; these mutations have all been confirmed by PCR amplification and Sanger sequencing. Mutation analyses, competition experiments, and transcriptome analyses are being utilized to reveal the adaptive role of these genes in LP growth of *Bacillus subtilis*.

This research is supported by NASA grant NNX08AO15G to W.L.N. and a NASA Earth and Space Science Fellowship (NESSF) fellowship to S.M.W.

**[SP.20]** Effects of Hindlimb Unloading on the Expressions of Angiopoietin1 and Tie-2 in Mouse Skeletal Muscles.

A. Ikuta, A. Goto, M. Suzuki, T. Ohira, T. Egawa, Y. Ohno, T. Sugiuira, Y. Ohira, T. Yoshioka, and K. Goto. 1Department of Physiology, Graduate School of Health Sciences, Toyohashi SOZO University, Toyohashi, Aichi, Japan; 2Department of Exercise and Health Science, Faculty of Education, Yamaguchi University, Yamaguchi, Japan; 3Graduate School of Medicine, Osaka University, Toyonaka, Osaka Japan; 4Hiroasaki Gakuin University, Hiroasaki, Aomori, Japan.

Skeletal muscle has a remarkable plasticity in response to various physiological or pathological conditions. It is generally accepted that skeletal muscle-specific stem cells, so-called muscle satellite cells, play an important role in skeletal muscle plasticity. It is well-known that angiogenic genes, such as vascular endothelial cell growth factor (VEGF) and angiopoietin 1/Tie-2, play a key role in the maintenance of capillary networks. Recently, it has been reported that angiopoietin 1/Tie-2 signaling regulates the cell cycle of muscle satellite cells. Therefore, it is suggested that angiopoietin 1/Tie-2 signaling may be one of the molecules that communicate between skeletal muscle and capillary to regulate both capillary architecture and skeletal muscle mass. However, the responses of angiopoietin 1 and Tie-2 expressions to unloading remain unclear. In the present study, we investigated that the changes in the expression levels of angiopoietin 1 and Tie-2 in unloading-associated atrophied skeletal muscle. Male ICR mice (11 weeks old) were used. The mice were randomly assigned into 2 groups: hindlimb unloading (n = 6) and cage control (n = 6). Following 2 weeks of hindlimb suspension, soleus and plantar muscles were dissected from both groups of mice under anesthesia with i.p. injection of sodium pentobarbital (5 mg/100 g body weight). Expression levels of angiopoietin 1 and Tie-2 were evaluated by Western blotting and real-time RT-PCR. Muscle wet weights of plantaris and soleus muscles were decreased by hindlimb unloading (p < 0.05). Decreases in the expression levels of angiopoietin 1 and Tie-2 were observed in these muscles vs. the cage controls (p < 0.05). Since both angiopoietin 1 and Tie-2 are responsible for morphological changes in skeletal muscle, vascular...
INVESTIGATOR AND STUDENT POSTER SESSION  
TUESDAY, NOVEMBER 5, 2013 (6:00 PM – 8:00 PM)

endothelial cells and muscle satellite cells may cross-talk via angiopoietin 1/Tie-2 signaling.  

Changes in bacterial proliferation and susceptibility to antibiotics during spaceflight have been noted since the beginning of the U.S. and Soviet space programs. Regarding altered population growth, decreased lag phase and increased final counts are commonly reported in prior spaceflight experiments. In terms of susceptibility to antibiotics, spaceflight experiments have been shown to need up to four times the antibiotic concentration to prevent bacterial growth relative to a normal Minimum Inhibitory Concentration (MIC) obtained in 1g. These two phenomena are being concurrently investigated in the laboratory with the use of clinostats to simulate a reduced gravity environment around the bacterial cell. A novel method of inclining clinostats to simulate micro- 1/6 and 1/3 g is described. Cultures of E. coli are being evaluated using BioServe’s flight hardware on these clinostats. Optical density measurements are being used to characterize baseline (i.e., no drug) lag phase durations and final cell concentrations. The bacterial cultures are then grown in different concentrations of gentamicin sulfate to assess their susceptibility to the drug under each of the three simulated gravitational environments relative to 1g controls. Antibiotic concentrations of ½, 1, 2, 4 and 6 times MIC are being tested. Preliminary data have shown differences in basic bacterial growth as a function of gravitational regime similar to prior findings. Additional testing currently underway. 
Supported by BioServe Space Technologies.

[SP.22] Microbiological Sampling Methods and Sanitization of Edible Plants Grown in Microgravity.  C.H. Parrish II¹, C.L. Khodadad², N.T. Garland³, B.D. Larson⁴, M.E. Hummerick⁵. ¹Department of Biological and Agricultural Engineering, North Carolina State University, Raleigh, NC, USA; ²Sierra Lobo, Inc.; ³Department of Agricultural and Biological Engineering, University of Florida, Gainesville, FL, USA; ⁴QinetiQ North America, Inc.; ⁵Advanced Life Support Labs, Surface Systems Office, NASA Kennedy Space Center, FL, USA.
Pathoenic microbes on the surfaces of salad crops and growth chambers pose a threat to the health of crew on International Space Station. For astronauts to safely consume space-grown vegetables produced in NASA’s new vegetable production unit, VEGGIE, three technical challenges must be overcome: real-time sampling, microbiological analysis, and sanitization. Raphanus sativus cultivar Cherry Bomb II and Lactuca sativa cultivar Outredegous, two salad crops to be grown in VEGGIE, were inoculated with Salmonella enterica serovar Typhimurium, a bacterium known to cause foodborne illness. Tape- and swab-based sampling techniques were optimized for use in microgravity and assessed for effectiveness in recovery of bacteria from crop surfaces. Rapid pathogen detection and molecular analyses were performed via quantitative real-time polymerase chain reaction using LightCycler® 480 and RAZOR® EX, a scaled-down instrument that is undergoing evaluation and testing for future flight hardware. These methods were compared with conventional, culture-based methods for the recovery of S. Typhimurium colonies. A sterile wipe saturated with a citric acid-based, food-grade sanitizer was applied to two different surface materials used in VEGGIE flight hardware that had been contaminated with the bacterium Pseudomonas aeruginosa, another known human pathogen. To sanitize surfaces, wipes were saturated with either the sanitizer or sterile deionized water and applied to each surface. Colony-forming units of P. aeruginosa grown on tryptic soy agar plates were enumerated from surface samples after sanitization treatments. Depending on the VEGGIE hardware material, 2- to 4.5-log10 reductions in colony-forming units were observed after sanitization. The difference in recovery of S. Typhimurium between tape- and swab-based sampling techniques was insignificant. RAZOR® EX rapidly detected S. Typhimurium present in both raw culture and extracted DNA samples. 
Supported by the NASA National Space Grant College and Fellowship Program and the North Carolina Space Grant Consortium.

In 1975, a malfunction aboard the spacecraft used in the Apollo Soyuz Test Project caused toxic gas to leak into the spacecraft, stopping the heart of pilot Vance Brand. The crew was able to use traditional CPR methods to resuscitate the pilot because they were in normal Earth gravity. However, as commercial space travel becomes more prevalent, the probability of cardiovascular incidents in microgravity will increase. To prevent a tragedy, it is important to improve the efficiency and effectiveness of cardiovascular related equipment in this new environment. The current NASA CPR procedure requires 3 to 4 minutes of preparation, two rescuers, and a large rigid surface that the patient can be strapped to. This can potentially be reduced to 90 seconds of preparation, one rescuer, and a small, free-floating strap system using our active compression decompression cardiopulmonary resuscitation (ACD-CPR) procedure. In addition to the compressions of regular CPR, our procedure actively decompresses the chest using a suction device. This device has been shown to improve coronary artery pressure by 30% over traditional CPR. 
To begin the procedure, the rescuer attaches himself/herself behind the patient with a strap restraint, places the device on the victim’s sternum, and then performs ACD-CPR. Effective CPR requires at least 100 compressions per minute at a depth of compression of 2 inches. The compressions simulate the heart beating which drives 5000 ml/min of blood through the body and heart. The team is testing to determine whether the necessary depth and rate of compressions can be achieved using our method. In space our method would be preferred to traditional methods because it requires smaller equipment, is more versatile, and decreases rescue time. Our procedure was tested aboard NASA’s “Weightless Wonder” microgravity aircraft both in June 2012 and in June 2013. The preliminary results show it is possible to achieve the rate and depth of compressions necessary for effective resuscitation with our procedure. 
Our thanks to Advanced Circulatory Systems, Missouri University
of Science and Technology, and Phelps Regional County Medical Center.

[SP. 24] NASA ARC Human Performance Centrifuge: Evaluation and Reduction of Centrifuge Rider Anxiety through Progressive Centrifugation. Morgan Carille 1,2, Margaret Cheng-Campbell 1,3, Peter Hatch 1,4, Daniel Morgan 5, Fritz Moore 6, Jon C. Rask 7. 1 Lockheed Martin Space Life Sciences Training Program, Space Biosciences Division, NASA Ames Research Center. 2 Washington University in St. Louis Department of Biomedical Engineering. 3 University of California-Davis, Department of Molecular and Cellular Biology. 4 San Jose State University College of Engineering, Mechanical and Aerospace Engineering Department. 5 Flight Systems Implementation Branch, Space Biosciences Division, NASA Ames Research Center. 6 Lockheed Martin Space Operations, Space Biosciences Division, NASA Ames Research Center. 7 Dynamaic, Inc., Space Biosciences Research Branch, Space Biosciences Division, NASA Ames Research Center.

The 3.8 meter Human Performance Centrifuge (HPC) at NASA Ames Research Center (ARC) is currently being utilized over a one month period to investigate the familiarization process of subjects using the HPC regarding the impact of rider anxiety and the best methods of anxiety reduction. Most studies conducted on ARC centrifuges including the HPC focus on cardiovascular responses to the artificial gravity environment.

Emotional stress including anxiety has long been known to affect cardiovascular variables such as blood pressure and heart rate. We hypothesized that anxiety in naïve centrifuge riders might alter cardiovascular responses to centrifugation and that repeated exposures to centrifugation would reduce anxiety related cardiovascular variation. It is expected from prior experience that three consecutive exposures will demonstrate the naïve rider anxiety response as well as its progressive decrease and give insight to minimum exposures required to familiarize subjects and eliminate anxiety related cardiovascular variability.

Twelve volunteer subjects are initially given a briefing and medical evaluation. Three identical centrifuge exposures (2 minutes of 1 Gz at feet) accompanied by three State-Trait Anxiety Inventory (STAI) questionnaires will be administered on consecutive days following by a control (no centrifuge motion) on the fourth day. This data is will be analyzed for progressive changes in anxiety indexes and compared with control data. It is hypothesized that rider anxiety in naïve subjects decrease following successive exposures to artificial gravity.

As of 1 July 2013, subjects have been recruited, briefed, and scheduled for further study. The HPC facility and protocol are both Human Research Institutional Review Board and Experiment-Readiness Review approved. Data from this study will be collected throughout July 2013. Changes in heart rate variability, blood pressure, and anxiety among the experimental groups will be tested using a two-factor analysis of variance and will be reported at the American Society for Gravitational and Space Research Conference on 3 November 2013. This research is supported by the Space Life Science Training Program (SLSTP) Lockheed Martin and the NASA ARC Space Biosciences Division.

[SP. 25] Examining the CO2 Dependent Relationships in a Membrane Aerated Biological Reactor Treating a Space-Based Wastewater. Dylan Christenson 1, Audra Morse 1, W. Andrew Jackson 1, Karen Pickering 1, Daniel Barta 1, Kevin Nguyen 1, Elizabeth Cummings 1. 1 Texas Tech University, Lubbock, TX, USA; 2 NASA Johnson Space Center, Houston, TX, USA.

In order to enable long term space habitation, sustainable advanced life support systems with minimal reliance on consumables are essential. Water recovery is a fundamental component of these systems, and Membrane Aerated Biological Reactors (MABRs) have been proven to be an efficient and sustainable process for extra terrestrial wastewater recycling applications that can eliminate the need for urine pretreatment and decrease loading on downstream processes. NASA is currently operating biological reactors in an integrated systems test based on a MABR design developed at Texas Tech University (TTU). In support of this test, CoMANDR (Counter-diffusion Membrane Aerated Nitrifying Denitrifying Reactor) was operated for the past year at TTU. The CoMANDR system was used to treat unstabilized wastewater composed of urine, hygiene water, humidity condensate, and laundry water. Influent wastewater values averaged 900 mg-N/L for total nitrogen and 575 mg/L for total organic carbon. Overall, >60% nitrification and >90% organic carbon removal efficiencies were maintained over various operational characteristics and loading scenarios. As part of this effort we evaluated the impact of the CO2 gas concentration on treatment efficiency and pH, two inter-related variables critical for reactor performance. In addition we also performed an evaluation of the microbial population after 1 year of operation. In a MABR, the flux of CO2 through the biofilm into the membrane lumen is controlled by the concentration gradient. When the system is operated at low gas flushing rates, the aqueous phase CO2 concentration can greatly increase due to microbial oxidation of organic matter. This increase leads to a decrease in pH and the subsequent inhibition of ammonium oxidation. Understanding the CO2 dependent relationships within an MABR are essential because the gas flow also impacts the oxygen concentrations within the reactor. The relationships among CO2 transport, production, biofilm activity, and nitrogen transformation and removal efficiency will be discussed in context with the spatial variation in microbial ecology. The researcher would like to acknowledge Dr. Audra Morse, Dr. Andrew Jackson, and the Water Reclamation Technology group at Johnson Space Center as well as the financial support provided by NASA and the Texas Space Grant Consortium.

[SP.26] Developing a Cube Sat Experiment to Study the Neurobehavioral Changes in Drosophila melanogaster in Space. S.Pandey 1, C.Angadi 1, T.Lusby 1, S.R.Shankar 1, J.Smith 1, S.Schery 1, K.Long 1, C.Reddy 1, S.Bhattacharya 1. 1 Space Biosciences Division, 2 Fluid Mechanics Laboratory, NASA Ames Research Center, Moffett Field, CA USA.

Spaceflight is known to induce oxidative stress in biological organisms. Fruit flies (Drosophila melanogaster), a genetically well-characterized model organism, will help us better understand the effects of long term altered gravity exposure on neurobehavioral function, locomotion, and the mechanics of insect flight. The primary aim of this experiment is to study the locomotion and flight pattern changes in the fruit fly during spaceflight and relate these changes to alterations in oxidative stress pathways. A secondary aim
is to understand mechanics of insect flight under altered gravity. A genetic mutant line that has an increased amount of resistance to oxidative stress pathway will be used to test its ability to withstand Space-stresses. A special visual tracking arrangement monitors the movement of the flies in 3D space under microgravity. This paper will describe the design, development and testing of the modular package to be used on board the International Space Station. A standard Cube Sat enclosure was chosen and all requirements were met to interface with the Express Rack on ISS. Numerous constraints, such as sustaining a healthy fly population for the duration of the mission, gathering 3-D video data within a constrained physical space, and adhering to power and mass budget limitations had to be considered while designing this payload. The final design required the development of various subsystems and components that included the fly habitat to hold two separate genetic lines of flies, a camera, a power system, an on-board computer, and lighting and other related electronics. Commercial (COTS) components were used for the subsystems, leading to a highly cost-effective assembly and a rapid development time. Test data will be presented to show the functionality of the current system and steps taken to optimize it. The experiment is scheduled to fly on the International Space Station (ISS) on the SpaceX4 flight. Supported by STC, NanoRacks and ASGSR and NASA grant NNH09ZTT003N/FS809PROP-0022 to SB.

[SP.27] Electro-Hydrodynamic Manipulation of Bubbles in Microgravity. Dana Qasem, Dr. Boris Khusid, Dr. Ezinwa Elele, Dr. Yueyang Shen, Dr. John Tang. Department of Chemical Engineering, New Jersey Institute of Technology, Newark, New Jersey.

The lack of the gravity-driven gas-liquid phase separation in microgravity has compromised a wide range of space technologies. The main idea behind the proposed electro-hydrodynamic (EHD) method for driving bubbles is to generate a local oscillatory fluid flow and a dielectrophoretic force by applying an alternating current field directly to a fluid via capacitive coupling to external electrodes. Contrary to the currently available direct current field-based microgravity techniques, the EHD method employs flow and field-induced forces to drive bubbles and suppresses electro-chemical reactions at the fluid-electrode interface. The parabolic flight tests were conducted in July 2013, aiming to validate the EHD method for the control and manipulation of bubbles in microgravity. These results will be presented at the conference.

This work is supported by NASA grant NNX09AK06G.

[SP.28] Germination and Growth Vigor of Arabidopsis Seedlings in High Density Polyethylene. Tony Briceno1,2,3, Joshua G. Chen1,2,4,5, Dr. Robert Bowman1,3,4. SLSTP Summer Intern, 2Space Bioscience Botany Laboratory, 3Mitchell Community College, 4Carnegie Mellon University, 5NASA Ames Research Center, Moffet Field, CA, 94035.

This research is part of a NASA summer student project to investigate the plant biocompatibility of commonly used plastics in space construction. Plants are sensitive to chemicals found in plastics. This sensitivity affects the germination and vigor of plants. Three commonly used plastics were tested for biocompatibility: Natural Colored high density polyethylene (HDPE), white HDPE, and Delrin. Two experiments were conducted with different levels of substrate exposure. In the first configuration, Arabidopsis thaliana cv. Columbia seeds were placed in flight-ready root modules constructed out of each plastic, and mounted using growth paper, putting them in direct contact with the HDPE. In the second configuration, Arabidopsis seeds were placed on top of growth paper, which was set on top of the HDPE, giving them indirect exposure to the HDPE. The seeds with indirect contact with the HDPE all had 99+% germination rates and did not show any signs of altered growth vigor. Seeds grown in direct contact with the root modules had similar germination rates but showed reduced growth vigor in natural colored HDPE. Time-lapse photos, analyzed using image analysis software, indicate that Arabidopsis grown in direct contact with natural colored HDPE have reduced cotyledon surface area. These data suggest that natural HDPE and potentially other plastics are not suitable for use in the design of lunar and deep space plant habitats.

[SP.29] Numerical investigation for the thermocapillary flow observed in “Saturday-Morning-Science” conducted by Dr. Donald Pettit. T. Yamamoto1, Y. Takagi1, Y. Okano1, and S. Dost1.

1Department of Materials Engineering Science, Osaka University, 1-3 Machikaneyama, Toyonaka, Osaka 560-8531, Japan; 2Crystal Growth Laboratory, University of Victoria, Victoria, British Columbia, V8W 3P6, Canada.

NASA astronaut Dr. Donald Pettit carried out a series of simple science experiments on the International Space Station (ISS) in 2003 and 2012 through a program called “Saturday Morning Science”. In one of the experiments of 2003, he reported a thermocapillary flow in a thin water film formed in a circular ring. The flow developed in the film was towards the heated section of the ring, which is opposite to the usual thermocapillary flows observed on Earth (hot to cold). In the experiment conducted in 2012 however, thermocapillary flows were observed in both directions (towards both cold and hot sections). To shed light on these observations and also to understand the mechanism governing the flow direction, we have carried out a numerical simulation.

The simulation was conducted using the OpenFOAM package. In the simulation, the deformation of the free surfaces due to the thermocapillary flow was neglected. Shapes of the static free surfaces were determined in two ways: one by using the approximate Young-Laplace equation, and the other by considering an arbitrary meniscus shape. The wire/water interface was assumed to be flat in both cases. To reduce computational cost, diameter of the water film was selected smaller: 10mm. The film thickness was taken as 0.2 mm.

The simulation results show that the water film shape is the key factor in determining the flow direction. When the water film volume is large leading to a convex water film shape, the developed flow is towards the heated region. However, when the film volume is smaller and consequently the water film surfaces are concave, the developed flow is towards the cold section. Results also show that, when the water film is concave and the arbitrary meniscus shape is very sharp, the flow is towards the heated section. As a conclusion we may state that the shapes of free surfaces and meniscus determine the direction of developed flows.

This research was financially supported by Grant-in-Aid Scientific Research (B) (no. 22360343) from the Ministry of Education, Culture, Sports, Science, and Technology of Japan, and by Collaborate Research Program for Young Scientists of ACCMS and IIMC.

The current method of environmental cooling on the International Space Station is a two-fluid, single-phase system in which liquid water is circulated through Station to absorb heat, and then is brought into conductive contact with pipes containing anhydrous ammonia that dissipate this heat into space. The two-fluid, single-phase system on the ISS relies on sensible heat transfer and is less efficient than two-phase, single fluid heat transfer systems relying on latent heat exchange. Long-duration spaceflight will necessitate advancements in spacecraft heat dissipation and will likely rely on two-phase heat exchange systems. The Flow Boiling and Condensation Experiment (FBCE) scheduled for deployment on the ISS in 2017 will provide the first data on heat transfer rates and condensation dynamics in reduced gravity. The FBCE will serve as a first step toward developing two-phase cooling systems for future spacecraft. A significant technical challenge of two phase heat exchange systems is the removal of dissolved gases introduced into the coolant fluid during condensation. Dissolved gases (primarily atmospheric oxygen) reduce the effective heat capacity of the fluid, making the cooling less efficient. Therefore, a method of de-gassing coolant in microgravity environments is needed before two-phase cooling systems can be practically implemented. In the work reported here, we demonstrate a method of de-gassing of the dielectric coolant FC-72 (perfluorohexane) using a radial membrane contactor. The method was tested in the reduced gravity environment of parabolic flight. The tests were conducted as part of NASA’s Systems Engineering Education Discovery (SEED) program. A team of seven undergraduate students designed and built a flow-loop to measure and characterize the efficiency of the RMC in extracting dissolved oxygen from the liquid perfluorohexane. Dissolved oxygen content as a function of flow rate and ambient conditions were measured and compared with 1-g laboratory testing. Data from the microgravity tests will be used to inform the design of the flow boiling and condensation experiment being developed at NASA-GRC.

This work was supported in part by a grant from the Wisconsin Space Grant Consortium.

[SP.31] Effect of Oxygen in Liquid Zr on Surface Oscillation of Electrostatic Levitated Droplets. Kenta Onodera1, Manabu Watanabe2, Akitoshi Mizuno2, Masahito Watanabe1, and Takehiko Ishikawa2. 1Department of Physics, Gakushuin University; 2Japan Aerospace Exploration Agency, JAXA.

We can measure the viscosity of high-temperature liquid from the surface oscillation data using the electrostatic levitator even on the ground14, since we can generate the single mode oscillation of levitated liquid droplets with small radius of about 1mm. It is well known that liquid metal viscosity affects dissolved oxygen14, However, the effect of oxygen inside liquid on the surface oscillation has not been clarified. In order to clarify the effect of dissolved oxygen on the surface oscillation, we observed the surface oscillation of liquid Zr contained oxygen of 500 (ppm mass oxygen: PMO) and 1000PMO. These samples were prepared by the art melting of crystalline Zr samples with ZrO2 powders. From the observation, we found that the surface oscillation amplitude and damping were different with waiting time for surface oscillation generation after melting of samples. The difference is caused by the diffusion of oxygen in liquid Zr from its inside to the outside of droplets. If oxygen diffuses out completely from inside droplets, we will be able to obtain the viscosity of pure liquid Zr. However, if oxygen still remains inside droplets, the viscosity shows large value rather than that of pure liquid Zr. From the viewpoint of diffusion of oxygen in liquid, we need long time waiting to start the measurements in order to obtain the viscosity of pure liquid Zr. These results showed clearly the effect of dissolved oxygen on the viscosity. For the future ISS experiments, we must more study of oxygen effect on viscosity using electrostatic levitator on the ground. This work was supported by JAXA and JSPS KAKENHI Grant Number 24360316. Reference: [1] P.-F. Paradis etal., Rev. Sci. Instrum. 72, (2001) 2811; [2] T. Harada etal., MRS online Proceedings, 1528(2013) 426.

[SP.32] Dropwise Condensation on a Radial Gradient Surface. A.M. Macner, S. Daniel, and P.H. Steen. School of Chemical and Biomolecular Engineering, Cornell University, Ithaca, NY, USA.

Distributions of drops arise from dropwise condensation, evolving by nucleation, growth, and coalescence. Being able to manipulate droplet distributions is important to heat transfer enhancement, which is crucial to NASA’s management of waste heat generated under low gravity from electronics and habitable environments. This study examines how surface functionalization affects drop growth and coalescence. Transient dropwise condensation of water from a vapor phase onto a cold and chemically treated surface is studied. Experiments are carried out in a condensation chamber with constant generation of steam and constant cooling. Surfaces are treated by silanization to deliver either a spatially uniform contact-angle (hydrophilic, neutral, and hydrophobic) or a radial gradient of contact-angles (hydrophobic to hydrophilic). The time evolution of drop-size distributions and number-density are reported. For a typical condensation experiment on a uniform contact-angle surface, the growth curves advance through two regimes: an increase in number-density as a result of nucleation and a decrease in number-density as a result of larger scale coalescence events. In the absence of a removal mechanism, the fractional coverage of a uniform contact-angle surface, regardless of treatment, approaches unity. The drop-size distributions progress through four different shapes along the growth curve, with the initial and final shapes being the same. In contrast, for a radial gradient surface where removal by sweeping occurs, the number-density increases and then levels off to a value close to the maximum number-density. Consequently, only two distribution shapes are observed and the final steady-state distribution is similar to the initial distribution. Here, the surface-energy gradient is the removal mechanism and the fractional coverage leveled off at .3. Finally, the sweeping rate, characterized by the drop-size distribution evolution and the shape of the growth curve, affects the overall heat transfer.

This work was supported by a NASA Office of the Chief Technologist’s Space Technology Research Fellowship.

Self-assembly, spontaneously forms precisely organized structures by thermodynamic equilibrium, has been promised an efficient and cheap manufacturing process for functional devices and materials with novel or enhanced properties. Especially, the chemical and geometrical anisotropy of colloidal building blocks is promised to enable the selective interactions with directionality and specificity which provide higher complex structures. Still, most building blocks are based on spherical particles, which have limitation to form highly complex structures. We present the self-organization of Janus microparticles with chemical and geometrical anisotropy using semimicrogravity environment. Anisotropic Janus particles are made in two-step micromolding method, by first polymerizing trimethylolpropane triacrylate (TMPTA) monomer as a hydrophobic part, and subsequently polymerizing polyethylene glycol diacrylate (PEGDA) monomer as a hydrophilic part in Janus particles. Additional 3D shape control (e.g., concave or convex) of the particles can be achieved by manipulation of curvature at an interface. Self-organization of Janus particles can be achieved through the use of an orbital shaker, which is considered as a semi-microgravity environment and giving rise to make random collisions. We find that hydrophobic part of Janus cylinders with flat top can selectively bind in polar solvents and make dimer formation, whereas assembly of Janus particles with convex top allow for micelle-like formation. The hydrophobic interaction can be tuned by changing composition of solvent mixture, which allows us to vary the number of particles in a single cluster.

This research was supported by the Space Core Technology Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Science, ICT & Future Planning (NRF-2013M1A3A302042262).


Janus particles, just like molecular surfactants, could potentially function as effective colloid stabilizers for numerous multiphasic systems such as emulsions and foams. Thus, it is significantly important to understand interfacial behaviors of Janus particles at microscopic levels. However, many theoretical and experimental works have only focused on the behavior of Janus sphere due to simple geometry and easy preparation, so it still needs to fully understand the behavior of Janus particles with more complex shape at oil-water interface.

Here, we study the configurations and interactions of Janus cylinders at oil-water interface. Anisotropic Janus particles have both hydrophilic and hydrophobic parts are polymerized by using micro molding. We found that Janus cylinders at oil-water interface exhibit the two types of configuration, such as upright and tilted. Especially, we observe the strong lateral capillary interaction between tilted Janus cylinders with high aspect ratio (A.R=2.4) at oil-water interface. These results imply that aspect ratio of Janus cylinders has a significant impact on the configuration at oil-water interface, which can be explained by the presence of two minima in the attachment energy profile. Consequently, we expected that the understanding of Janus cylinders self-assembly provide a tool for fundamental study such as a particle-particle interaction and the utilization of particles as colloid surfactants in practical applications. This research was supported by the Space Core Technology Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Science, ICT & Future Planning (NRF-2013M1A3A302042262).

[SP.35] Effectivity of Xenon as Fire Suppressant under Microgravity Combustion Environment. M.E.A. Fahd, F.L. Dryer and T.I. Farouk. 1Department of Mechanical Engineering, University of South Carolina, Columbia, SC, USA. 2Department of Mechanical and Aerospace engineering, Princeton University, Princeton, NJ, USA.

Since 2009, the Flame Extinguishment (FLEX) program on board the International Space Station has been developing fire-safety protocols via microgravity droplet combustion experiments. A wide variety of hydrocarbon fuels (alcohols, alkanes) under varied environmental condition has been studied. One of the important focus has been to identify suppressants that are effective under ‘zero’ gravity conditions. Therefore, study on the influence of diluents on microgravity combustion and subsequently on flame extinction characteristics can shed lights on fire extinguishment phenomena. In this study, numerical simulations have been conducted to investigate the combustion and extinction characteristics of isolated methanol droplets burning in a xenon enriched environments. For comparison, identical conditions in argon diluent were also studied. The study was conducted for initial droplet diameters ranging from 1.0 – 3.0 mm in size. The results show distinct combustion and extinction behavior. Increasing xenon concentration resulted in slower burning rate, larger extinction but longer total burn time. It is found that the limiting oxygen index (LOI) under xenon enriched conditions were significantly lower than that observed in the nitrogen or argon. The predicted combustion characteristics are in good agreement with recently conducted experiments onboard the ISS. The numerical results are further analyzed to determine the dominant factors that produce such lower LOI in xenon. The results of this computational study are also compared with published helium and carbon-dioxide enriched environment droplet combustion data in order to assess the diluents effect.


Thermocapillary convection is the flow driven by the presence of a surface tension gradient which can be produced by temperature difference at a liquid-gas interface. It is known that the convection transits from steady to oscillatory flows when the temperature difference becomes higher than certain critical point. The critical temperature difference depends on several governing parameters such as Prandtl number of fluid, aspect ratio of liquid column, shape of liquid bridge, heat transfer at the interface and so on. Several hypothetical models are proposed about size dependence on the critical temperature difference [1, 2]. Microgravity experiment utilizing the International Space Station was performed to determine
the critical temperature difference in case of large liquid column. The experiment facility was set in the Japanese Experimental Module "KIBO" of the ISS. A 50 mm diameter liquid column was formed and the temperature difference was imposed at the both end of liquid column to induce Marangoni convection. The temperature difference was changed step by step. Consequently, convection transited from steady to oscillatory flows and the critical temperature difference could be determined. We made clear the effect of aspect ratio and size of liquid column on the critical condition. And the mechanism of onset of oscillatory flow will be discussed. References [1] S. Yoda et al. , Microgravity sci. technol., Vol.16, pp.269-273 (2005), [2] Y. Kamotani et al., J. Heat Transfer, Vol.120, pp.758-764 (1998).

[SP.37] Synchronization of dust acoustic waves under microgravity conditions. W. D. Suranga Ruhunusiri and J. Goree. Dept of Physics and Astronomy, The University of Iowa, Iowa City, Iowa, USA.

Dusty plasmas are mixtures of charged microparticles consisting of solid matter, electrons, ions, and gas atoms and they occur naturally in tails of comets, the rings of Saturn, and interstellar nebulae. The charged microparticles exhibit collective motion, including waves and instabilities. The particles can be seen with the naked eye and can be imaged directly by video microscopy. Microgravity conditions enable experiments that are not practical under 1g conditions because the particles sediment. ESA’s PK-4 instrument, due to launch in 2014, is devoted to dusty plasmas. Parabolic flight tests with a breadboard version of PK-4 indicate that the plasma exhibits a dust acoustic wave (Fortov et al., Plasma Physics and Controlled Fusion, 2005; Usachev et al., Czechoslovak Journal of Physics, 2004), which is a compressional wave, due to an ion flow. In this talk, results from a ground-based breadboard experiment are described (Ruhunusiri et al., Physical Review E, 2012). Nonlinear synchronization is an adjustment of a wave’s frequency in response to an external periodic modulation. We characterize synchronization of the dust acoustic wave by varying both the amplitude and frequency of an external electrical modulation. The dust acoustic wave has a very low frequency of about 20 Hz, and the modulations in the microparticle concentration are recorded using a high speed camera. Image analysis is our primary diagnostic of the wave. The wave frequency for different external modulation conditions are estimated by a Fourier transform of a time series of the image brightness. Synchronization was observed over a wide range of frequencies and amplitudes of the external periodic modulation. This work is supported by NASA’s Physical Science Research Program.


Dendrites form during solidification into an undercooled melt and develop secondary arms, which undergo a coarsening process. There is a close relationship between the size scale of the coarsened dendritic structure and the mechanical properties of the material. Yet, as the microstructural evolution of secondary dendrite arms remains poorly understood, there is a need to characterize the morphological and topological evolution of the dendritic structures. In the microgravity environment on the International Space Station (ISS), one can better follow the evolution of the morphology of the mixtures in the diffusive limit as well as the topology of the solid-liquid mixtures, since the sedimentation velocity is about 6 times slower than on earth. Four sets of directionaly solidified Pb-Sn samples with volume fractions of 10%, 20%, 30% and 40% were sent to the ISS on March 1, 2013. The samples of each set were heated at 185°C, 2°C above the eutectic, in the solid-liquid region of the phase diagram, for a variety of durations (10 min, 1.6 hr, 5.5 hr, 13 hr, 27 hr and 48hr). They were returned on March 26, 2013. An automated serial sectioning method is used to generate 3D representations of the dendritic structures. A combined use of LVDT, Mutual Information and cross-correlation, and montaging of multiple images, allows for a more detailed measurement of the microstructure. A preliminary analysis of sections of all 24 samples shows that for the 10% samples, the dendritic structure disappeared rather quickly, but that no sedimentation occurred during coarsening. For the 20% samples, the dendritic structure is still present after 1.6 hours; that in some areas the dendrite arm is splitting up and that nearly spherical particles have replaced the dendrites after 13 hours. For the 30% samples, the structure remains relatively unchanged from the 10 min sample to the 1.6 hour sample; that after 5.5 hours the primary dendrites have split up while the secondary arms have coarsened together; and that after 13 hours, the primary arms have completely disappeared. For the 40% sample, the structure remains dendritic throughout. Further results of the experiments will be given.

Supported by NASA Grant NNX10AV36G.

[SP.39] Numerical Simulations of TLZ Crystal Growth Process of SiGe under Microgravity. Keita Abe1, Sara Sumioka1, Ken-ichi Sugio1a, Masaki Kubo2, Takao Tsukada2, Kyoichi Kinoshita2, Yasutomo Ara1, Yuku Inatomi2. 1Tohoku University, 2Japan Aerospace Exploration Agency (JAXA).

Single crystals of SiGe, especially Si0.5Ge0.5, attract the attentions as the post Si semiconductor substrates which enable to produce high-speed and low energy electronic devices. Recently, Kinoshita et al. [for instance, J. Crystal Growth, 349, 50 (2012)] have developed the traveling liquidus-zone (TLZ) method for the production of homogeneous SiGe bulk single crystals. Although homogeneous SiGe single crystals with diameters of up to 30 mm were successfully grown by the TLZ method, the growth of larger diameter crystals for semiconductor devices was not succeeded yet, because free convection induced by the temperature and concentration gradients in the melt affects the homogeneity of the crystals on the ground. In order to clarify the effect of free convection on the TLZ crystal growth of SiGe, therefore, the crystal growth experiments under a microgravity environment in International Space Station (ISS) have been planned and are being performed this year by JAXA. In this work, to understand transport phenomena in the TLZ crystal growth process of SiGe under microgravity, especially to explain the experimental results of the SiGe crystal growth performed in ISS this year, a mathematical model for the crystal growth process of SiGe by the TLZ method has been developed under the assumption that the system is axial symmetric. The self-made code based on this model can predict numerically the velocity field in the melt, the thermal fields in the melt, crystal and crucible, Si concentration fields in the melt and crystal, and the melt/crystal interface shapes. The boundary conditions for temperature at the outer wall of the crucible were determined by a global analysis of heat transfer in the TLZ furnace using a commercial software FLUENT. Here, we
investigated the effect of operational conditions, e.g., the furnace speed, thermophysical properties of the crucible, and crystal radius, on the spatial homogeneity of grown single crystals and the melt/crystal interface shape which are macroscopic characteristics related to the crystal quality. In addition, the experimental results obtained in the ISS were compared with the numerical ones by the above model.


Coarsening is a diffusion driven process by which the total energy of a system is reduced via the reduction of interfacial area. In a two-phase system consisting of solid precipitates in a liquid phase, this occurs through the growth of large precipitates at the expense of small ones, evolving from many small precipitates to a few large ones. A robust understanding of this process is of particular importance in the design of precipitate hardened alloys, especially those used in high temperature applications, such as the turbine blades in jet engines. Despite the many theories predicting coarsening behavior, there is a surprising lack of experimental data to test these theories. Most studies have either been two-dimensional studies of cross sections or three-dimensional studies on too small a scale to acquire statistically significant data on the particle densities. We present results from the Coarsening in Solid Liquid Mixtures (CSLM) experiment flown on the International Space Station (ISS), designed to bridge this gap. PbSn alloys of varying solid volume fractions were coarsened over a range of times and then analyzed using mechanical serial sectioning. From 3D reconstructions of the microstructure of the alloys, the average particle size, particle density and particle size distribution (PSD) can be measured and tracked as the samples coarsen. The observed evolution of the particle size is consistent with the temporal law predicted by theory and the rate constant describing this evolution shows agreement with predictions from simulations at low volume fractions. In addition, the evolution of the particle density is measured for the first time and is shown to be consistent with the temporal evolution predicted by Lifshitz, Slyozov and Wagner. Observed PSDs are shown to be consistent with results from simulations of coarsening using the Akaiwa-Voorhees (AV) theory.


In order to manufacture spherical crystals of semiconducting materials, containerless solidification, where the melt is levitated and solidified without using a crucible, has been carried out. Until now, this process has been analyzed on the basis of the dendrite growth model proposed by Lipton, Kurz and Trivedi (hereafter referred to as LKT model). The solidification behaviors of metals and alloys are well analyzed by this model. To semiconductors, however, it is unreasonable to apply this model, because in the LKT model, the crystal-melt interface is assumed to be rough. Recently in semiconducting Si, Watanabe, Nagayama and Kuribayashi proposed the modified dendrite growth model where instead of the linear kinetics the exponential description was employed as the rate-controlling kinetics. In the present investigation, extending their idea to the case where the alloying elements are doped, the containerless crystallizing of Sn doped Ge was performed and the influence of alloying on the solidification kinetics was analyzed. Samples were Ge-1%Sn alloy, which were melted from semiconducting grade Ge and 6N Sn. Containerless solidification was carried out with an electro-magnetic levitator equipped with a CO2 laser. Solidification process was monitored with a high-speed video camera (HSV). To measure the temperature of the sample we used a mono-color pyrometer. Experimental results showed the solidification velocities of Ge-1%Sn alloy were higher than those of pure Ge at high undercooling as well as at low undercooling. In metallic materials LKT model predicts that impurities sharpen the dendrite-tip and therefore result in the enlargement of the solidification velocities particularly at low undercooling. In semiconducting Si and Ge, however, it has been known that the crystal growth can be controlled by the nucleation at the re-entrant corner formed at the edge of the twin-boundaries. In this case, the crystal growth should be controlled through the twinning kinetics. In the present study, we developed the twinning controlled crystal growth kinetics based on “Impurity Induced Twinning”.


In order to understand the solidification path in undercooled Fe-Co alloys, the metastable phase diagram must be evaluated from thermodynamic modeling of the free energy of each phase as a function of temperature and composition. The metastable portion of the phase diagram was found by suppressing the stable phase while adjusting the parameters used in Gibbs free energy analysis for the theoretical bcc Co phase until there was good agreement with experimental data. Subsequently, both the thermal driving force for the bcc-to-fcc transformation and the partitioning coefficient of the metastable bcc-phase were determined as a function of cobalt composition. These results are used in the modeling of transient nucleation processes to compare results observed in ground-based to future space-based rapid solidification experiments.

Funding for this work was provided by NASA under grants NNX08ALZ1G and NNX10AV27G.
All members are invited to attend the committee meetings being held during the Annual Meeting and are encouraged to commit to continued involvement in the committee activities throughout the year. The committees have direct interaction with the board and can make a difference in the success of the society.

**JOURNAL COMMITTEE**

*Chair: Dr. Anna-Lisa Paul, University of Florida*

The Journal Committee prepares and solicits articles relevant to ASGSR interests for ASGSR publications and other journals, including international publications, as well as providing technical reviewers upon request. The journal committee supports outreach activities that promote the advancement of gravitational and space. At minimum, the Journal Committee should annually:

- Solicit input and assemble the articles for ASGSR publications, including the ASGSR refereed journal.
- Provide an editor(s) for ASGSR publications.
- Promote the Society’s publications, including providing access to the publications for Society members through the website.
- Provide guidance with regards to the evolution of ASGSR publications.
- Facilitate the promotion of ASGSR authored articles to the general public and lay press.
- Provide input for the ASGSR newsletter and website.

**COMMUNICATIONS COMMITTEE**

*Chair: Dr. Kevin Sato, Lockheed Martin/NASA Ames Research Center*

The Communications Committee prepares and solicits articles relevant to ASGSR interests for ASGSR publications and other journals, including international publications, as well as providing technical reviewers for such journals upon request, and supports outreach activities that promote the advancement of gravitational and space biology. This committee can also coordinate the development of position or white papers (also a role for the external affairs committee). The ASGSR Web site will be monitored by the committee, with a member(s) designated as content manager. Inputs from other ASGSR committees will be passed through the Communications Committee prior to publication on the Web site. At minimum, the Communications Committee should annually:

- Solicit input and assemble the articles for ASGSR publications.
- Provide an editor(s) for ASGSR publications.
- Promote the Society’s publications, including providing access to the publications for Society members through the website.
- Annually update and prepare the ASGSR membership-marketing brochure and make it available to membership committee and members to distribute at appropriate events.
- Provide content updates for the ASGSR Web site as needed.
- Provide input for the ASGSR newsletter.
- Facilitate the promotion of ASGSR authored articles to the general public and lay press.

**EDUCATION AND OUTREACH COMMITTEE**

*Chair: Ms. Kimberly Slater, CSS-Dynamac*

The Education and Outreach Committee is responsible for developing strategies, tools and materials for use by the ASGSR membership in support of industry, academia, federal government, and general public events. The committee promotes and conducts education activities (student poster and design competitions) and can develop specific items (short courses, meeting workshops, videos, slides, tools and materials, etc.) to increase knowledge and awareness of gravitational space and research throughout ASGSR sponsored public and professional forums. Annually, ASGSR supports the Graduate and Undergraduate Student Poster Competition at the annual meeting. This committee would be responsible for coordination and administration of the competition. At minimum, the Education and Outreach Committee should annually:

- Coordinate participation in the ASGSR student poster competition including promoting event and recruiting student competitors.
- Organize and select judges for the ASGSR student poster competition. The student poster competition includes cash awards that are pre-determined annually.
- Update slide sets on ASGSR Web site.
- Develop and coordinate outreach event(s) for the annual meeting. (e.g., STEM workshop, visits to local schools, etc.). If the event requires funding, it must be coordinated with the conference chair and ASGSR executive director.
ASGSR Committee Descriptions

EXTERNAL AFFAIRS COMMITTEE
Chair: Ms. Cindy Martin-Brennan, ASGSR
The External Affairs committee is responsible for organizing the ASGSR’s involvement with key policy makers and other professional organizations that promote ASGSR’s positions and key issues. The committee, with coordination by the ASGSR board and executive director, develop key messaging for the society. The messaging can be short-term and long-term (i.e., strategic). This committee provides assistance in updating and publishing educational materials used for policy makers and will coordinate with other organizations (e.g., AIAA) to establish cooperation, keeping in mind future plans of jointly held sessions and workshops at ASGSR conferences. This committee will also be active in inviting state and local ASGSR members to key meetings. At minimum, the External Affairs Committee should annually:

- Prepare and organize ASGSR positions and key issues with coordination and approval by the ASGSR board and executive director.
- Coordinate and implement monthly round robin external affairs meetings.
- Coordinate development of position papers (also a role for the Communications Committee).
- Facilitate collaboration with other organizations.
- Coordinate appropriate activities with ASGSR local, regional, and student members.

MEETINGS AND WORKSHOPS COMMITTEE
Chair: Dr. Joseph Tash, Univ of Kansas Medical Center
The Meetings and Workshops Committee is responsible for assisting the conference chair in organizing technical sessions for the ASGSR annual meeting and occasional workshops. The ASGSR president of two years prior (past Past President) serves as the Program Chair for the Annual Meeting. Each year, this committee will work with Program Chair to identify funding sources and provide support to the chair in the development of grant funding proposals for the annual ASGSR conference (e.g., forming basis of grant request by developing technical sessions). The committee will also work with the ASGSR executive director to identify candidate geographic locations for the annual meeting. The location is approved by the board of directors. The committee will also identify other venues for ASGSR technical participation, such as the AIAA Aerospace Sciences Meeting (ASM), ELGRA, and ISGP. If other venues are identified, the committee submits a short proposal to the ASGSR board of directors, and executive director for approval, especially if there is an anticipated expenditure of funds. The committee will coordinate with other conference committees for joint sponsored conferences, co-located meetings, and workshops. At minimum, the Meetings and Workshops Committee should annually:

- Support ASGSR conference chair for annual conference participation planning.
- Assist the executive director in identifying annual meeting locations.
- Seek and coordinate joint venue activities at other conferences (e.g., ASM, ELGRA, ISGP) that promote gravitational and space research.
- Assist the Program Chair in organizing technical sessions for the ASGSR annual meeting.

MEMBERSHIP COMMITTEE
Chair: Ms. Nicole Rayl, NASA Headquarters (geneLAB)
The Membership Committee recruits qualified new individuals who wish to promote gravitational and space biology and related technology development. Overall, the committee works to enhance ASGSR membership, working closely with the Executive Secretary, who maintains the membership database. The committee will work to keep balanced membership across organizations and fields of expertise and ensure that current members remain sufficiently active in ASGSR. In addition to planning recruitment of new members, the committee will develop and implement a plan reengage past members. At minimum, the Membership Committee should annually:

- Monitor member participation (meetings, voting and committee membership).
- Recruit new members (including international and student members) and follow up with welcome letters and information.
- Work with the Nominating Committee (standing committee) to identify candidates for the board of directors and president-elect.
A Tribute to Dr. Michael J. Wargo
A Great Contributor to Low-Gravity Research and Lunar Exploration

Michael J. Wargo, passed away on August 4, 2013. He was 61 years old. Dr. Wargo was a leading contributor to NASA’s human lunar/planetary exploration and microgravity research programs.

Dr. Wargo exerted a major influence on the Microgravity Science Program in the former Office of Biological and Physical Research. He helped to formulate NASA’s mission for low-gravity research during the 1990’s through 2004. More recently, as a scientific member of many lunar missions, including the Lunar Reconnaissance Orbiter and the LCROSS satellite, Dr. Wargo helped map resources for human missions to the moon and participated in the discovery of ice in the shadows of lunar craters. His former work as discipline scientist in materials science created an expansion to the physical science investigations conducted on Shuttle, Spacelab, Mir, and ISS. During the Spacelab era he served as Mission Scientist for the USML-1 mission.

In a nearly two-decade career at NASA, he received numerous awards including NASA’s Exceptional Service Medal and seven group achievement awards. He was a member of the team planning the next robotic mission to Mars in 2020 and worked gathering crucial scientific information needed to allow humans to be sent safely to the moon, Mars and near-Earth asteroids. Much of his work has helped develop a "roadmap" for human and robotic space exploration for the next two decades.

Mike Wargo came to NASA Headquarters when the Microgravity Sciences Division (MSD) was just beginning its growth in preparation for the development of the hardware and research programs for the International Space Station. His energy and excitement about the possibilities of human research in space coupled with his magnetic personality were the keystones of his leadership in the materials science community. While increasing the number of researchers involved in the Materials Science Program, Mike assisted in establishing a peer review process that won praise from the National Academy of Sciences while attracting some of the most highly respected researchers in the field. In addition, he enhanced his reputation as an “uber nerd” by serving for a time as the IT expert for the MSD. His commitment to education was evidenced by his leadership in developing and publishing a teacher’s manual with experiments and lessons to increase the interest of young students in science, technology, engineering and math over a decade before STEM became a buzz word for the education field. Mike’s expertise in the materials science field cannot be measured. His reputation is acknowledged by the numerous invited talks he gave around the world. Even more important was Mike’s willingness to mentor young researchers and students as well as his enthusiasm in recruiting well-known researchers who were unaware of the potential of space research.

Dr. Wargo graduated from Massachusetts Institute of Technology, with an SB degree in Earth and Planetary Science and received a Doctorate in Materials Science in 1982. At MIT, he was recognized with the John Wulff Award for Excellence in Teaching and the Hugh Hampton Young Memorial Fund Prize for exhibiting leadership and creativity while maintaining exceptionally broad and interdisciplinary interests. He began his career at NASA by turning a fledgling microgravity research division into a world-class program. NASA drew on Dr. Wargo's ability to explain complex scientific findings in straightforward terms as a spokesman at agency press conferences. NASA is asking the International Astronomical Union to name a crater on the moon in his honor "so his name will be forever enshrined in the heavens." His colleagues and his friends remember him as inspirational, full of passion and energy, with a booming voice and a great heart.

Mike exuded an infectious passion, dedication, and enthusiasm for forging closer ties between science and exploration at NASA, which he achieved because of his encyclopedic knowledge of science and exploration issues that are involved with human spaceflight and research. Mike’s passion for science, exploration and microgravity research can be seen in multiple mission videos.

In addition, Mike was a very good friend and ardent supporter of MIT’s Department of Materials Science Engineering, from the time of his doctoral work with Professor August Witt through his research appointments at MIT and up to the present. Mike’s university friends all mention his good humor, his resounding voice, and his generosity with his time and expertise.

Dr. Wargo will be missed by all of us both within NASA and the research community.
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